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Engineering and Mining Journal

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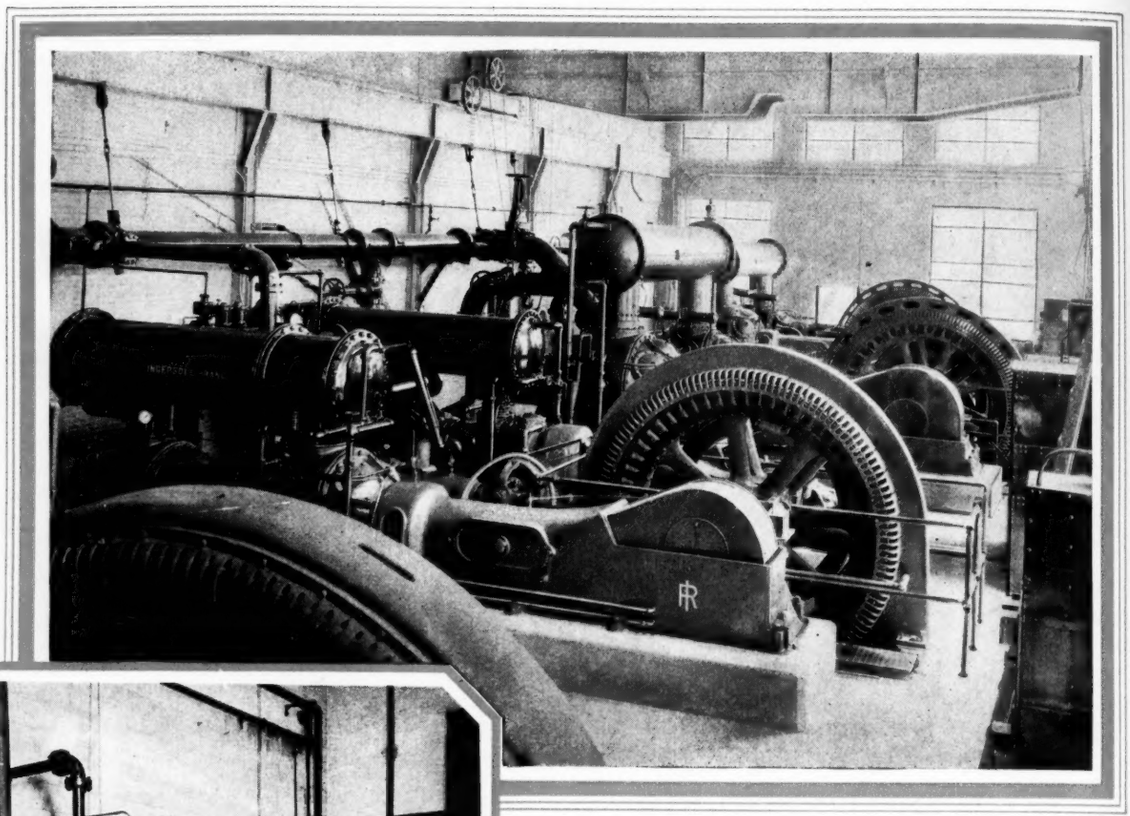
Gold Mining and Milling

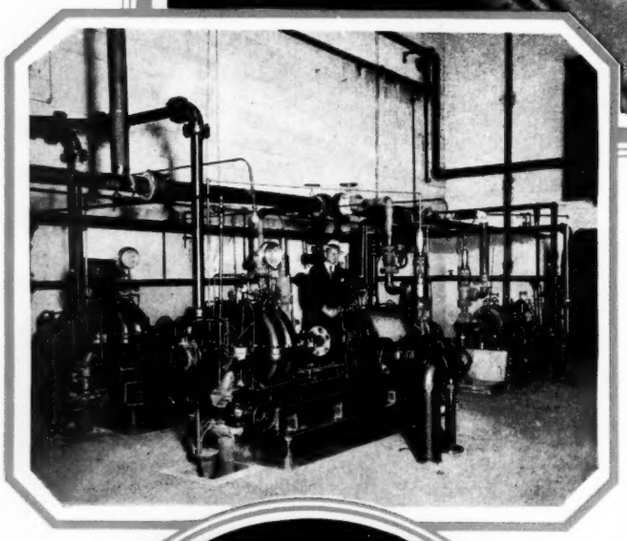
At Lead, South Dakota

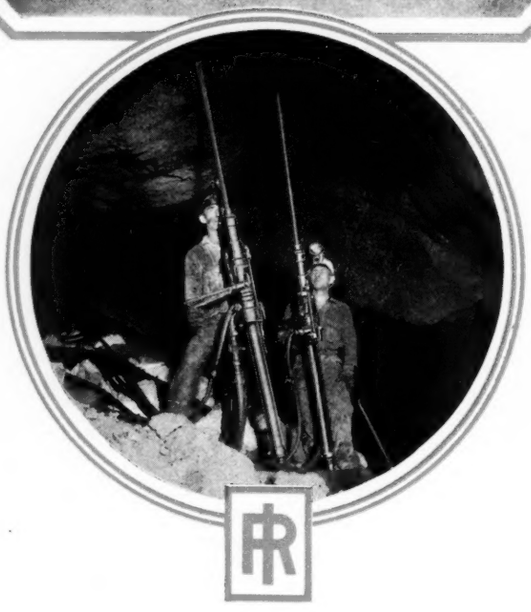
1876-1931

The Homestake Enterprise

World Statistics and Charts of the Gold Mining Industry







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EPIC IN GOLD

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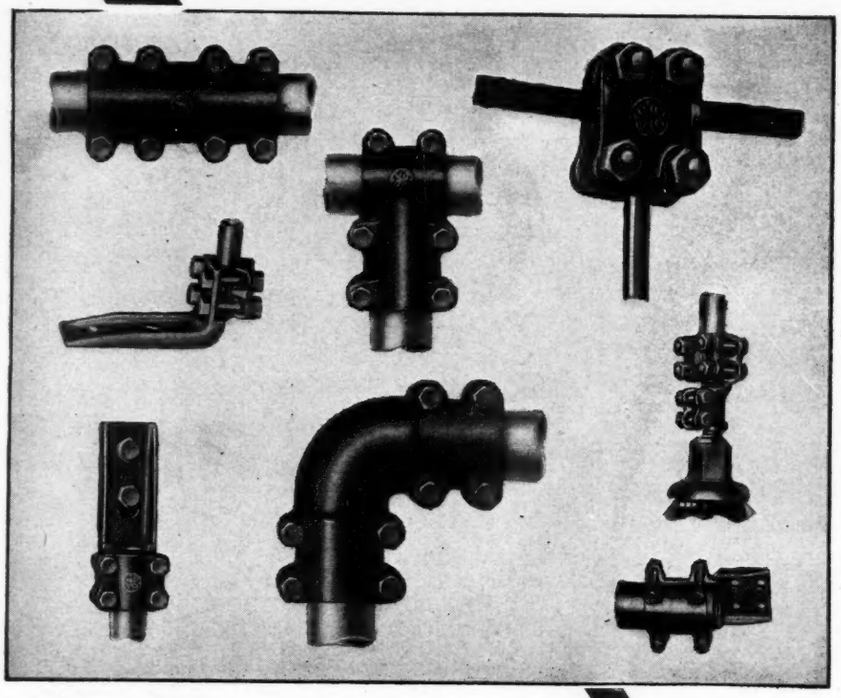

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Engineering and Mining Journal

October 12, 1931 A. W. ALLEN, *Editor* Vol. 132—No. 7

THE HOMESTAKE ENTERPRISE

. . . The record of performance of the directors and operating officials of a mining company is not always easily appraisable. A casual critic is inclined to infer that favorable natural factors, if in evidence, are mainly responsible for satisfactory technical and financial results. But the easy path is the sure road to decadence, if not to failure; and the impartial investigator who is seeking a reason for uninterrupted progress will therefore look beneath the surface.

. . . Many vicissitudes have marked the long and honorable career of the Homestake Mining Company, although an observer may point to circumstances that have exerted a favorable influence, such as the appreciation of reserves, maintenance for several decades of physical uniformity in the character of the ore, availability of a ready market for the product at a stable and fair price. Nevertheless, a study of history compels acknowledgment of the fact that the company's status is the outcome of pioneering grit, wise leadership, and capable supervision, rather than an example of a characterless exploitation of a valuable deposit.

. . . Development of a low-grade mine calls for caution as well as courage, two qualities the application of which has made the Homestake property what it is today. As a governing force in the evolution of an operating technique in mine and mill and shops, and in the utilization of subsidiary resources, this dual moral influence has been directly responsible for a significant addition to the gold reserves of the United States and of the world.

. . . Many mining properties that have "lived beyond their means"—in tune with the politico-economic philosophy prevailing until a few years ago—have come to an inglorious end. Their directors have failed to realize that the fulfilling of duties and obligations of service to state and community connotes planning well into the future, to insure security for all direct and indirect dependents. More important than mechanical efficiency and financial gain is the contribution that good management makes to national stability by the practice of a concern and a loyalty in the attitude of employer toward employee, an attitude that makes for human contentment, that spurs initiative and energizes performance.

. . . In this respect the Homestake company has made a signal contribution to contemporary sociology. During half a century of operations the enterprise seems to have been guided by an unproclaimed maxim that internal friction is harmful and destructive. Help and cooperation have proved of benefit to all concerned. Bickering or adverse criticism is conspicuous by its absence.

. . . Technicians will be impressed by the achievements at Lead and vicinity, as chronicled in this issue; but the psychologist and the humanitarian will probably be among the first to discover an important underlying reason, if not the major contributing cause: The directors of Homestake operations have been ahead of their time in acting on the truism that the Machine Age calls for special attention to the personal element, in developing the more constructive and less provocative phases of human thought and action.

A. W. Allen

Homestake History . . . Then and Now

REPORT OF COMMITTEE ON STOCK LIST
NEW YORK STOCK EXCHANGE

Jan. 16, 1879

Official Statement of the Homestake Mining Company

Incorporated under laws of California, Nov. 5, 1877.
Capital, 100,000 shares, par $100—$10,000,000.
Property located in Whitewood Mining District, Lawrence County, Dakota Territory; consisting of Homestake and Golden Star Mines, 1,350 ft. long by 450 ft. wide on the vein; title complete.
Improvements: New 80-Stamp Mill fully equipped, hoisting works, air compressors, tramways, tools, sawmills, offices, and houses.

Value	$250,000
Receipts to Jan. 1, 1879	475,500
Expended in development, construction, etc	387,000
Balance Jan. 1, 1879	$ 88,500

Present capacity of mill, 175 tons per day; mine can supply 500 stamps; ore in sight sufficient to run present mill ten years.
A new mill with 120 stamps has been ordered to be completed in June next; when completed the crushing capacity will be over 400 tons per day.
No debts, liens, or encumbrances of any kind or nature.
New York office, 31 Broad Street.

Transfer Office Wells, Fargo & Co., 65 Broadway
Registered by Union Trust Company

Officers

President	Lloyd Tevis
Vice-president	R. P. Lounsbery
Treasurer	J. B. Haggin
Secretary	J. K. Goodrich
Assistant Secretary	H. B. Parsons

Directors Lloyd Tevis, J. B. Haggin, R. P. Lounsbery, Thos. Bell, M. L. McDonald, Wm. Willis.

The committee recommends that this stock be placed on the regular list.

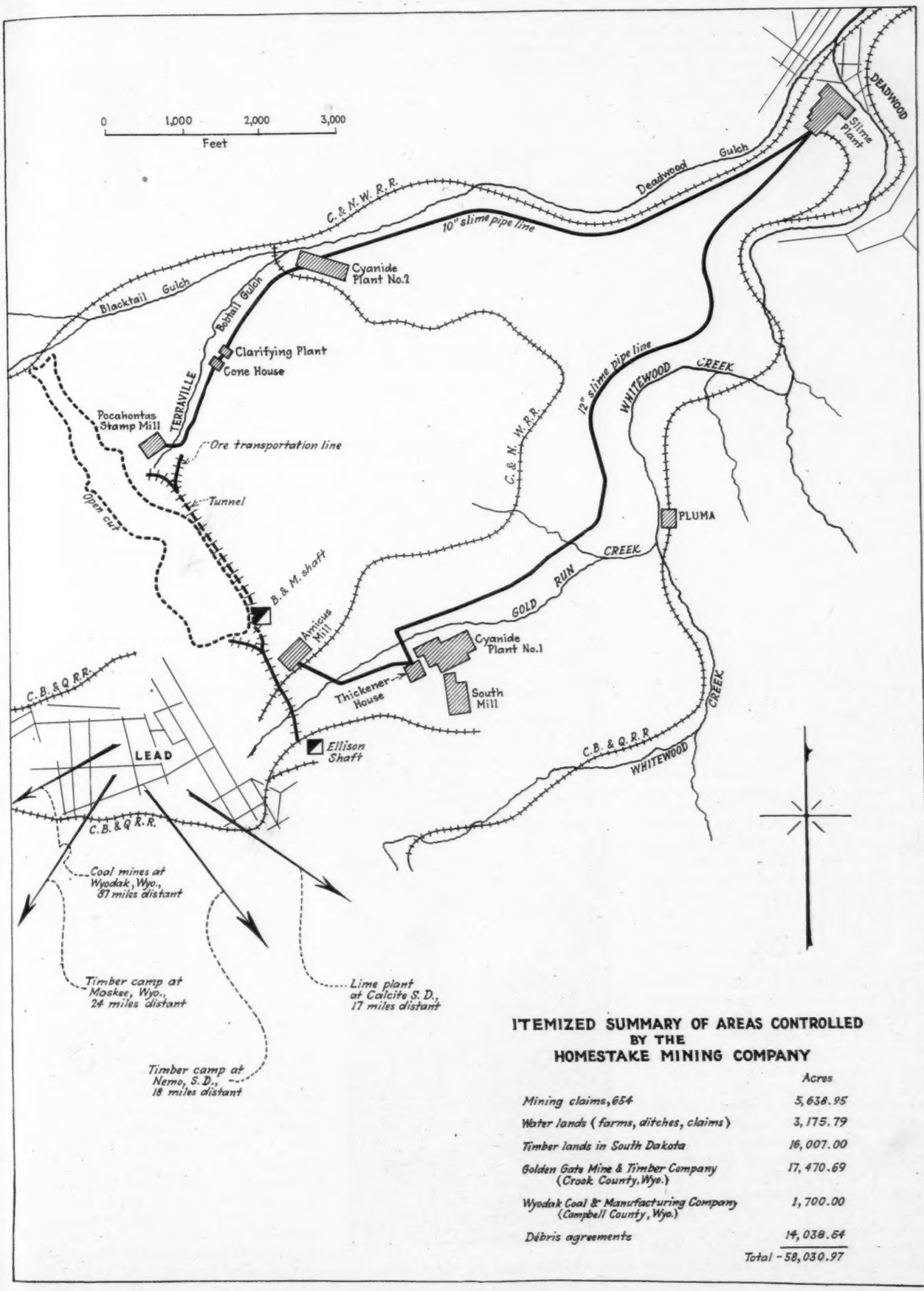
AB'M B. BAYLIS, Chairman.
Adopted by the Governing Committee, Jan. 22, 1879.

UNFORTUNATELY, many of the historic records of the Homestake Mining Company were destroyed in the San Francisco fire of 1906, and complete figures of tonnage treated are therefore unavailable. However, between January, 1879, when the ore reserves were officially given as about 700,000 tons, and December, 1930, the total gold recovered amounted to 12,325,544 oz., valued at $254,768,997. At the end of this period the ore reserves were reported as totaling 15,657,561 tons. . . . The report of the Committee on Stock List of the New York Stock Exchange (1879) and the most recent annual statement of the company (1930) provide comparative data of unusual interest and inspiration.

STATEMENT OF OPERATIONS FOR THE YEAR ENDED DEC. 31, 1930

Operating Revenue:			
Bullion—			
Proceeds of bars 7464–7767		$8,426,195.21	
During the year 1,364,456 tons of ore were milled, realizing an average of $6.1755 per ton.			
Golden Gate timber operation		28,218.82	
Wyodak coal operation		34,558.57	
Interest and rents		178,542.91	$8,667,515.51
Operating Expenses:			
Mining, hoisting, and primary crushing		$3,277,336.08	
Tramming		29,761.72	
Milling		763,402.86	
Express on bullion		9,433.69	
Employees' Welfare—			
Hospital	$66,745.55		
Workmen's Disability Compensation	27,513.92		
Aid Fund	2,617.50		
Benefices	7,120.00		
Pensions	34,294.77		
Recreation hall	32,325.02		
		170,616.76	
Taxes		510,887.51	
Insurance		27,091.30	
Salaries, office, legal and general expenses		201,056.59	
Loss Ellison hoist fire, less insurance		213,911.02	
Outside explorations; abandonments and investigation expenses		157,194.81	$5,360,692.34
Income			$3,306,823.17
Charges Against Income:			
Reserved for Depreciation and Depletion			1,813,952.56
Net Income			$1,492,870.61
Dividends for the Year:			
Paid from earnings			$1,506,960.00
Paid from depletion reserve			502,320.00
Total for year			$2,009,280.00

Detail Map of Operations



ITEMIZED SUMMARY OF AREAS CONTROLLED BY THE HOMESTAKE MINING COMPANY

	Acres
Mining claims, 654	5,638.95
Water lands (farms, ditches, claims)	3,175.79
Timber lands in South Dakota	16,007.00
Golden Gate Mine & Timber Company (Crook County, Wyo.)	17,470.69
Wyodak Coal & Manufacturing Company (Campbell County, Wyo.)	1,700.00
Débris agreements	14,038.64
Total -	58,030.97

History

In age, continuity of operations in the mining and beneficiation of a low-grade ore, in bullion yield, in its disbursements of wages and dividends, the Homestake property stands at the head of the great gold mines of the world. In the early stages of an unusually long career for a producer, it founded the fortunes of George Hearst, whose connections with this industry were memorialized by the benefactions of his widow, Phoebe, notably to the College of Mining of the University of California, the State from which the venture was planned and originally directed, and to the town of Lead, in South Dakota. . . . The history of the Homestake enterprise has been uninterrupted by frequent changes of management and policy. Since the incorporation of the company in 1877 it has had but four directing executives in charge of operations: Samuel McMaster (1877-84); T. J. Grier (1884-1914); Richard Blackstone (1914-18); B. C. Yates (1918-). Few alterations in technical practice have been made. In the second half-century of a career of achievement and purpose, the company possesses a background of experience that will prove of value in maintaining its position in the van of the leading gold producers in the Americas, one hopes for many more years to come.

Edward H. Clark
President

Fred. T. Elsey
Vice-President

Industrial and Technical Development

Early in 1877 the members of a San Francisco syndicate, consisting of George Hearst, Lloyd Tevis, and J. B. Haggin, dispatched a typical mining engineer of those days, Samuel McMaster, to report on a silver mine near Deadwood, S. D., the outcome of which was not favorable. While in the district, however, he investigated the worth of gold claims in what was known as Gold Run Canyon, which resulted in the purchase of two claims, known as the Homestake and the Golden Star, respectively, less a strip of land 10 ft. wide originally deeded by the owners to H. B. Young, who had staked the claims in 1876. This strip was subsequently acquired.

The Homestake Mining Company was incorporated in San Francisco in November, 1877, with a capitalization of $10,000,000, which amount had increased in 1883 to $12,500,000, after the acquisition of claims owned by several other companies. In 1899, the capitalization rose to $21,000,000, permitting the purchase of the assets of another mining company, of a water company, and of a railroad—the Black Hills & Fort Pierre, sold to the Chicago, Burlington & Quincy company in 1902, when capitalization of the Homestake enterprise increased to $21,840,000, with the acquisition of the assets of the Deadwood-Terra Mining Company. In 1914 the capitalization stood at $25,116,000, in which year additional properties were secured. Present holdings of the company cover 5,638.95 acres, and comprise 654 mining claims, a coal deposit, timber lands, and water rights.

Under the superintendency of Samuel McMaster, the Homestake property was put on a producing basis in 1878, the first unit of the plant consisting of 80 stamps, of 750 lb. apiece, the parts of which were hauled by ox team over a distance of 270 miles from Sidney, on the Union Pacific Railroad. At that time

Timber stand at Nemo, S. D.

the ore from the mine was comparatively high grade. The stamps treated about 200 tons per day, and a yield as high as $14 per ton was reported. By August, 1879, a new 120-stamp mill had been completed, which raised the daily total tonnage to 525. By the end of 1880 the grade of ore had dropped to $6 to $7 per ton, but tonnage was up to 900 daily, and 580 stamps were dropping in the year that followed. By July, 1882, a total of 620 stamps were operating. From then on occurred a regular decrease in the grade of the ore, with a considerable increase in the tonnage and a reduction in mining and milling costs. In the year 1884-85, mining expense was reported as $2.04 per ton; milling, $1.01, with a yield of $5.73 per ton from 213,190 tons. The steam stamp was tried in 1892, but proved a failure; so more California units were added, reaching a total of 540 in 1898.

As was the case with the majority of the other gold mines of the world, the introduction of the cyanide process gave a new lease of life to the enterprise, by permitting the recovery of gold in the tailing after amalgamation had extracted the greater part. An experimental plant to handle about 60 tons per day was erected in 1899, the results from which prompted the design of a unit of fourteen 600-ton leaching vats, to treat 1,200 tons per day. Thereby the gold in the tailing sand was being recovered, but not that in the slime. In 1906 a filter-press plant was built, which completed the metallurgical treatment of the Homestake ore, insuring a high technical recovery of gold at a low unit cost. The influence of C. W. Merrill dominated the metallurgical technique being evolved during this period.

The success achieved in the application of the cyanide process at Lead is all the more significant because the early stages of the work were carried on at a time

when skepticism was rife, particularly in regard to the scope for cyanidation in the Black Hills region. As an illustration, an editorial in the May 21, 1892, issue of *Engineering and Mining Journal* stated that:

> "In regard to the merits of the [cyanide] process it may be said that while favorable testimony is scarce, the process has certain but limited applications. . . . It has been claimed that a MacArthur-Forrest plant was in existence at Deadwood, South Dakota, . . . the facts are that the process had been tried at the Golden Reward Works, which are now using, with great technical and commercial success, the barrel chloridizing process . . . and that cyanide had proved a failure."

The inference to be drawn from this comment is that the cyanide process, like every other new process, needed intelligent application, which characterized its utilization at the Homestake plant.

Metallurgical practice at Lead and vicinity, consisting in the amalgamation of easily recoverable gold; the gravity leaching of sand tailing; and the filtration of slime in sluicing presses, has been continued, with uninterrupted success, from 1906 to the present day. A description of practice at the company's mills and cyanide plants, with details of current metallurgical technique, contributed by Allan J. Clark, metallurgist, will be found in subsequent pages of this issue.

The history of the Homestake enterprise has not been without its colorful incidents, but space forbids the repetition of details. Suffice to say that it has, from its inception, fulfilled its major purpose as an industrial enterprise—to return adequate dividends to its stockholders and to safeguard their capital. Under the capable direction of its first superintendent, profits commenced soon after the initial clean-up from the first stamp mill erected at Lead. A dividend was paid early in 1879, and disbursements to date have continued regularly, except for a suspension during one quarter in 1907, when a shutdown was necessary because of a fire in the mine, and at a few times subsequently because of short interruptions to steady operations.

During the 55 years the company has been operating, up to the end of 1930, 12,325,544 troy ounces of gold has been produced, or 422½ short tons, in bullion valued at $254,768,997. Dividends disbursed prior to 1931 have totaled $59,626,804. The grade of ore has shown improvement in recent years. In 1929 1,437,935 tons were milled for a return of $4.53278 per ton, compared with 1,364,456 tons, for a return of $6.1755, in 1930. For the first six months of 1931, the figures are 697,810 tons, for a yield of $6.51 per ton.

The Homestake Mining Company has been a stabilizing factor in the industrial life of South Dakota. In and around the mines and surface plants have grown communities of citizens whose future is intimately linked with that of the company, which employs a total of 1,600 men in its mines and plants and offices, and contributes directly or indirectly to the support of local communities with an aggregate population of 10,000. Despite the lowered prices of commodities and the relative cheapness of living, the company has not lowered its wage rates in any department, thus maintaining its volume contribution to the buying power of the nation, and assisting to the limit of its power in the maintenance of economic stability.

No achievement of this character was ever carried through without the zeal and conscientious concern of every member of the organization. The articles that follow provide evidence of executive and technical ability essential to the success of an engineering undertaking. The rank and file of employees, as well as those in positions of trust and responsibility, share in the credit for having contributed to the progress of state, industry, and country.

Executive Direction and Social Engineering

The Homestake company represents one of the few large enterprises in the United States with a record covering over half a century of steady expansion —of commercial and engineering achievement. The effective coordination of its component parts has been the result of a balanced growth, under the direction and control of capable and zealous managers. Great responsibilities have been met, and many obstacles have been overcome, to an extent that illustrates the advantages of a close succession of uniform policies and the avoidance of indulgence in those radical changes that so frequently accompany reorganization programs. . . . The growth of the Homestake enterprise has been a slow but sure evolution in the direction of high engineering efficiency in mine and plant, influenced by the practice of a care in expenditure that has always kept the economic goal in sight. To the credit of those responsible, be it said that very few companies enjoy so complete a development of mutual helpfulness as is in evidence in the many units of this great organization.

B. C. Yates
General Manager

To appreciate the extent and character of the executive policies in force at the properties of the Homestake Mining Company necessitates a brief tribute to my predecessors and to the foundations for success they established. To the memory of the first superintendent, Samuel McMaster—an Irishman by birth and an American by adoption, with mining experience in Australia and California before he came to the Black Hills in 1877—the *Mining Exchange*, of San Francisco, paid this tribute in its issue of Jan. 8, 1885:

> "To no one man or set of men is greater credit due for the rapid and marvelous development of the mineral resources of the Black Hills than to the late Samuel McMaster. . . . Personally, Mr. McMaster was the embodiment of reserve—not the reserve of austerity, or superciliousness or arrogance, but rather that of a quiet nature in which there is no affectation. As a friend no warmer or firmer could be desired; as an enemy, none more implacable yet consistent, open and honorable, ever lived. A man of few words, he invariably said just what he meant, and invariably meant just what he said."

McMaster laid the foundation of a great industrial and engineering enterprise, of the future technical scope of which none could guess at that time. His successor, T. J. Grier, a native of Canada, brought to the venture the benefit of a close association with McMaster, together with a high degree of executive and organizing ability. He inculcated among the staff and the rank and file a respect for mutual regard and cooperative work. During his incumbency the company had the courage to adopt new metallurgical methods on a large scale. Grier had confidence in the radical innovations proposed by C. W. Merrill, a confidence that has been proved amply justified by results obtained throughout three decades, during a period that has seen the

suspension of operations of many a mine because of the technical inadequacy or complication of the metallurgical practice adopted.

The continuous and unvarying success of the Homestake plan of ore treatment has proved a powerful factor in the financial outcome of the enterprise, and an inspiration to the profession and industry of mining throughout the United States and abroad. Grier's major achievement, however, is indicated in the foundation he laid for the health and contentment of Homestake employees, and for the residents of Lead and other towns and camps within the scope of the company's operations. A recreation building, with theater, club, and library facilities, provides a center for the mental and physical recreation of the people of this mining community. A life-size bronze statue of Grier, who sponsored this development, which was supported financially by Phoebe Hearst and other members of the Hearst family, adjoins the entrance—a rare tribute to a mine superintendent.

Richard Blackstone, who succeeded Grier, brought to his task a knowledge of civil and mechanical engineering, gathered from an extensive railroad experience. During his régime the company expanded its interests in respect to hydro-electric plants and water supply facilities. In recent years, however, the company has entered a period that marked a conclusion of activities having for their purpose the acquisition of properties and rights, and the consolidation under centralized control of diversified operations of a technical or commercial nature.

The descriptive and technical articles that follow indicate that attention has been paid to provision against every conceivable emergency or eventuality that might hinder steady progress or prevent uninterrupted output. The Homestake company possesses extensive hydro-electric water rights, as well as a large and accessible deposit of coal. In addition, it has recently taken advantage of the availability of natural gas in the northwest section of the United States. Its timber rights, within a reasonable radius of Lead, are adequate for many years of operation. An excellent deposit of calcite is sufficent to meet requirements in regard to the supply of high-grade lime. An extensive piping system for the supply of water insures perpetual provision in this respect for domestic and metallurgical needs. The company, therefore, is in an exceptionally secure position in respect to its basic requirements, at an expense which has been favorably affected by the engineering skill that has characterized the development and utilization of these resources. Steps have been taken in recent months to reduce fire hazard in the older surface buildings, partly of wooden construction, by the installation of a modern sprinkler system.

The mechanization of operations on the Homestake properties has proceeded apace, during the past quarter century, as the articles that follow will testify. Electricity now plays an almost dominant rôle in the application of power. Labor requirements have decreased proportionately. For instance, the mining department employed 1,200 to 1,400 men thirty years ago for the extraction and transportation of an ore supply that is now effected with a personnel of only 650. Although surface work is almost entirely on a time-payment basis, the mine crews operate mostly on the contract system, which encourages and rewards according to individual effort. A steady gain in the efficiency of operations underground has counteracted, to some extent at least, the increasing cost of extraction and haulage from deeper workings and extended mine operations. Subsidence has occurred and is occurring within the city limits of Lead. This was anticipated, and complete preparations were made for all eventualities.

Social engineering is a comparatively recent branch of executive responsibility, but the Homestake company takes pride in the thoroughness of this phase of its operations. No expense has been spared to provide medical, recreational, and educational facilities, to prevent accident, to take care of the injured, to provide insurance against old-age survival, and to care for the dependents of employees. The company has also contributed largely to the support of church activities in the region in which it operates.

Hospital and medical service is free to all employees and to their dependents. A pension system, established in 1917, maintained solely at the expense of the company, provides that an employee may be retired on account of old age, physical disability, or disease. The basis of computation of pay after retirement is as follows: 25 per cent of the last full year's pay, plus $10 per year for each year of service. Since the inception of this system, 163 emloyees have been pensioned, 52 of whom are now receiving benefits. However, the company in its endeavor to better the social condition of its employees and of the other community dwellers has avoided a paternalistic attitude. Every effort has been made to encourage the development of an independent, free-thinking, and free-acting community of people, able to govern themselves as real Americans. As a result of this policy, the town of Lead has grown up to become a community of home owners who possess civic pride as well as loyalty to the company. The policy has ever been to recognize the rights of employees and to treat them fairly. Any employee, whatever his position, has ready access to the general manager to state a grievance or to suggest a new idea in regard to his work. The rewarding of loyalty and zeal has insured an unusual continuity of service. Six men are now in the employment of the company who have each worked for it continuously for 50 or more years. Advancement, so far as possible, is made from within the ranks. Several members of the present staff have been on the payroll for more than 25 years.

In 1905 a meeting was held of employees who had been in the service of the company for 21 years or more. The Homestake Veterans' Association was then formed and a constitution adopted, with the following avowed purposes: (1) to gather together at regular intervals the older employees of the Home-

B & M shafts and crushing plants

stake Mining Company; (2) to keep a record of incidents relative to the mine and its earlier employees; (3) to cultivate and keep alive an enduring friendship among its members. Entrants must be recommended by two veterans of good standing, and must show proof of good moral standing and character. The initial membership was 103. The association now boasts of a roll of 210. Employees who are retired on pension do not lose their membership. Although the personnel of the company is predominantly American in citizenship, a recent survey indicated that 23 nationalities were represented. All applicants for work must be able to read, speak, and write English, and to provide evidence that they have declared intention to become citizens of the United States.

No encouragement or help has been offered to employees to acquire stock in the enterprise. Coaxing, apparently, has not been necessary. A keen interest in the future of the company, coupled with a cofidence in the administration, has resulted in the acquisition of an extensive financial interest among all ranks of the organization, and throughout the State of South Dakota, excepting the management—indicative of a fixed policy pursued by Mr. Grier and followed by myself.

The Homestake company is justly proud of its record. Its mine plants, situated in one of the most picturesque regions of the United States, historically and scenically, are open to visitors, who enjoy the privilege to the number of about 12,000 per annum. Girl guides, from deserving Homestake families, are selected and trained as conductors of groups of tourists. These girls receive about $100 per month, as an aid to educational expense in school or college. A small charge is paid by the visitor, which provides the salary for the guide, any surplus being devoted to charitable or civic activities.

A feature of interest and convenience to visitors is what is known as Jubilee City—a group of buildings on each side of the road from Lead to Poorman Gulch—built in 1926 to commemorate the 50th anniversary of the discovery of the Homestake mine. The region, typical of the unsettled condition of the Black Hills half a century ago, is possessed of rare scenic beauty.

After the anniversary celebration, in August, 1926, the buildings were donated to the Homestake Aid Society, as a source of revenue for charitable purposes, the cabins now being rented for tourist accommodation. Additions have been made in recent years, and the settlement now consists of several buildings of native pine logs, suitable for two to twelve persons. Rates for the accommodation of tourists vary from $1 per day and upward.

Jubilee City is provided with electric lights, and natural gas for heating purposes. One cabin has a community kitchen, with a large range and adjoining dining rooms. A wash-room, with shower baths, is provided; also a community laundry. Supplies are available in a well-stocked store, and parking space for automobiles is provided. Water is piped to all parts of the camp, for domestic and fire protection purposes; sanitary arrangements throughout are complete and entirely modern.

Staff Coordination and Production Control

The secret of harmonious and efficient executive control depends to a large extent on the experience of the director of operations and the ability he possesses to manage himself. Discipline usually needs enforcement; but the example that comes from self-management is more effective than any show of authority. . . . The Homestake organization is a fine example of the value of an intimate interacquaintance of tasks, and a knowledge by heads of departments of exactly what is involved in the duties of subordinates. The visitor soon realizes, to an extent that compels admiration, that the company operates in the belief that understanding and loyalty of employer toward employee is as wise and as necessary as is faith and allegiance in the opposite direction; albeit that in the subordinate's acceptance of responsibility lies the major hope of his advance. Executive work at the Homestake properties demonstrates again that in union is strength; that group effort in an organization is best achieved by a generous supply of the catalyst of human sympathy.

R. G. Wayland
Asst. General Manager

As in all corporations, the stockholders of the Homestake Mining Company—the owners of the enterprise—elect a board of directors, whose duty it is to represent their interests and to determine the financial and other major policies of the corporation. The board elects officers to carry out its policies and to keep the corporation accounts, through a general manager it appoints. The general manager is the legal agent of the corporation in South Dakota, and is responsible to the president and board of directors for the success or failure of the enterprise. He has full authority over all operations, and is the ultimate authority in the solution of technical and managerial problems, and in the determination of local policies. Major items of new expenditure are submitted to the president. The general manager is also responsible for the choice of the staff and the heads of departments.

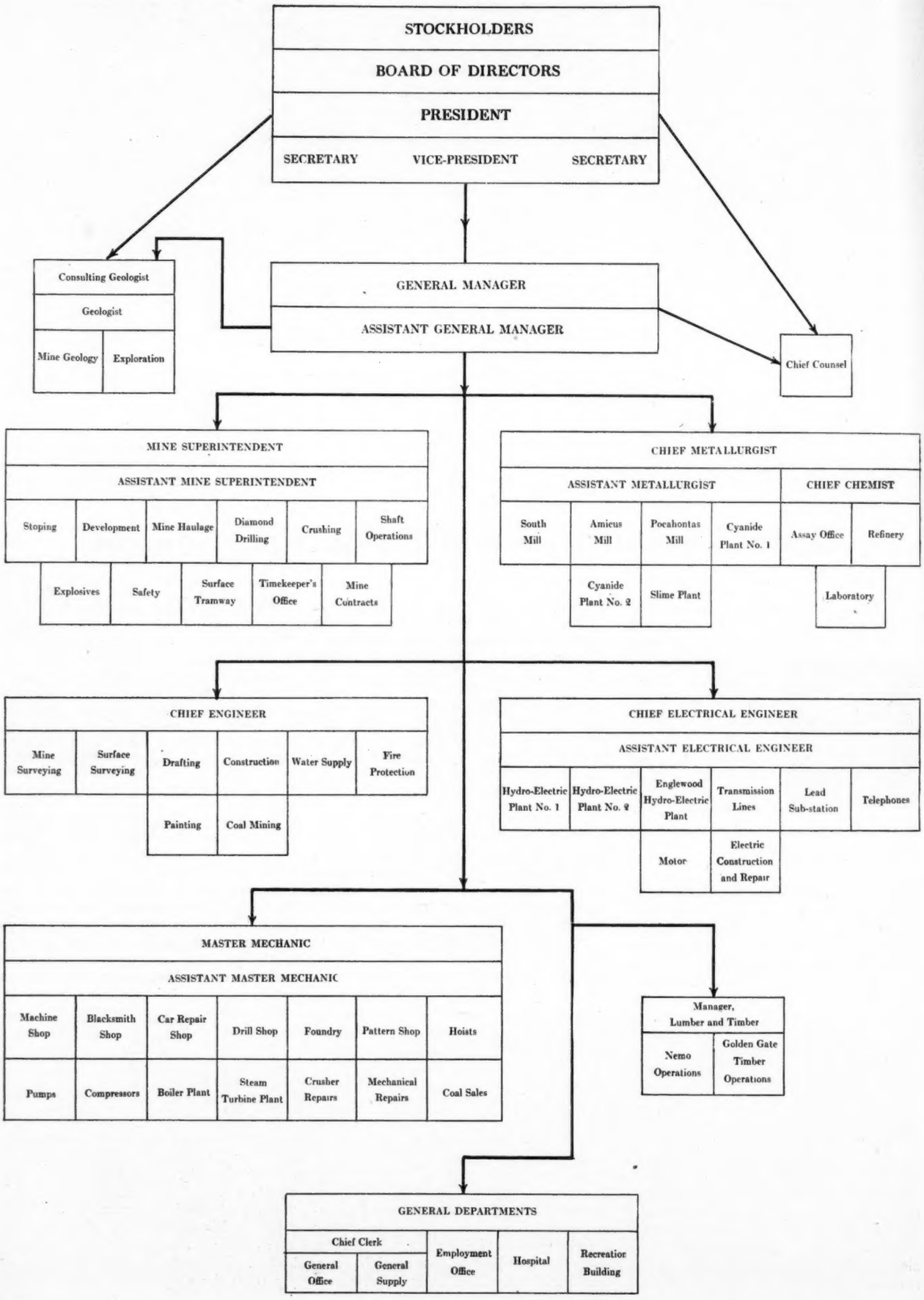
The assistant general manager, who assumes control of operations in the absence of the general manager, assists in coordinating the activities of the various departments, and in the executive superintendence of the solution of engineering problems. He assumes responsibility for auxiliary operations at the request of the manager, and in general is engaged in matters of a non-routine nature.

Responsibility for the direction of technical operations of an enterprise such as that of the Homestake company lies with the manager, but the scope of the enterprise is so great and the operations are so varied that one or two men cannot give each phase of the work the expert attention it requires. Detailed control, therefore, falls on the shoulders of those in active charge of the various departments. They are given full authority within their own spheres of control. They must answer to the manager for the results of their work, and must cooperate with the manager in correlating the work of their departments with that of the other departments.

The legal department is in charge of Chambers Kellar, an attorney of wide experience, whose department passes on questions of title, guides the payment of compensation, handles claims against the company, and represents it in court. Mr. Kellar is legal advisor to the president and general manager, and also to any department head whose work requires it. He also keeps in touch with the political situation as it affects the interests of the company.

The mine department is in charge of the mine superintendent, A. J. M. Ross, who has been with the company a great many years, first in the engineering department and later in the mine. With the advice and consent of the general manager he determines the method of mining and the development program, selects and operates underground equipment, and specifies material and supplies for his department. He appoints his assistants, the foremen, and the shift bosses. He requisitions his labor supply from the employment office, but he

Management


STOCKHOLDERS
BOARD OF DIRECTORS
PRESIDENT
SECRETARY
VICE-PRESIDENT
SECRETARY
Consulting Geologist
Geologist
Mine Geology
Exploration
GENERAL MANAGER
ASSISTANT GENERAL MANAGER
Chief Counsel
MINE SUPERINTENDENT
ASSISTANT MINE SUPERINTENDENT
Stoping
Development
Mine Haulage
Diamond Drilling
Crushing
Shaft Operations
Explosives
Safety
Surface Tramway
Timekeeper's Office
Mine Contracts
CHIEF METALLURGIST
ASSISTANT METALLURGIST
CHIEF CHEMIST
South Mill
Amicus Mill
Pocahontas Mill
Cyanide Plant No. 1
Assay Office
Refinery
Cyanide Plant No. 2
Slime Plant
Laboratory
CHIEF ENGINEER
Mine Surveying
Surface Surveying
Drafting
Construction
Water Supply
Fire Protection
Painting
Coal Mining
CHIEF ELECTRICAL ENGINEER
ASSISTANT ELECTRICAL ENGINEER
Hydro-Electric Plant No. 1
Hydro-Electric Plant No. 2
Englewood Hydro-Electric Plant
Transmission Lines
Lead Sub-station
Telephones
Motor
Electric Construction and Repair
MASTER MECHANIC
ASSISTANT MASTER MECHANIC
Machine Shop
Blacksmith Shop
Car Repair Shop
Drill Shop
Foundry
Pattern Shop
Hoists
Pumps
Compressors
Boiler Plant
Steam Turbine Plant
Crusher Repairs
Mechanical Repairs
Coal Sales
Manager, Lumber and Timber
Nemo Operations
Golden Gate Timber Operations
GENERAL DEPARTMENTS
Chief Clerk
General Office
General Supply
Employment Office
Hospital
Recreation Building

and his staff act personally in respect to dismissals. That function has not yet been delegated to a personnel officer.

At Homestake the mine superintendent requisitions the mechanical department for repairs and special equipment, and arranges with the master mechanic the hoisting, crushing, pumping, and compressor schedules. The engineering department does the necessary mine surveying and mapping. The geological department furnishes maps, working sketches, and forecasts; and the lumber and timber department furnishes mine timber on requisition.

In the scheme of operations the work of the mine department and the mechanical department are closely interlaced and require a fine sense of team work on the part of either or both. The mine operates the air drills; whereas the mechanics are charged with drill repairs and replacements. This is true, also, of underground and surface haulage. The mine operates underground and surface crushers and the skip loaders; whereas the mechanical department operates the hoists, and maintains all equipment in satisfactory condition. In addition to the mine superintendent, the underground staff includes an assistant mine superintendent, M. J. Vallandingham; four foremen who have charge of definite areas on day shift; a night foreman and assistant; shift bosses, powder foreman, and a safety engineer.

The metallurgical department is under the direction of Allan J. Clark, who has been identified with Homestake metallurgy since the beginning of the installation of the cyanide process. This department receives the crushed ore as it is delivered to the stamp-mill bins by the mine department, and is responsible for it until the gold bars are delivered to the American Express Company for shipment to the United States mint at Denver. Each of the three stamp mills and the three cyanide plants operates under a foreman reporting directly to the chief metallurgist or to the assistant metallurgist, R. Julius Hall. Chemical control, assaying and refining come within the domain of the chief chemist, Nathaniel Herz. In addition to determinations for his own department, Mr. Herz oversees the treatment of boiler water, regulates the application of chlorine to the city water supply, makes coal and mineralogical determinations, and tests explosives and hundreds of other commodities used in company operations. Materials and supplies used in this department are specified by the chief metallurgist and purchased through the general office.

The mechanical department is under the direction of the master mechanic, Sidney J. Staple, who has grown up in Homestake service, and has been highly successful in initiative and administration. This is the first of the service departments of the second group, and its activities cross the lines of every other department of the organization. Within this division come the machine shop, blacksmith shop, foundry and pattern shop, drill sharpening shop, car-repair shop, hoists, compressors, steam-boiler plants, steam-turbine plant, and the power plant and tipple at the coal mine. The master mechanic reports directly to the manager. He passes on the mechanical features of all new equipment, and makes recommendations on the renewal or retiring of old. His assistant, R. R. Pullen, a mechanical engineer, specializes in combustion, steam generation, heating, and allied lines. A great deal of his efforts go toward selling the product of the Wyodak Coal & Manufacturing Company, a subsidiary coal mining company.

Chief Electrical Engineer John F. Wiggert has charge of all electrical operations and maintenance. His department looks after dams, pipe lines, hydro-electric power plants, transmission lines, transformers, motors, and control. He reports directly to the manager. His assistant is Cedric L. Gust. In addition to operating and maintaining electric equipment, Mr. Wiggert and his staff perform the functions of consulting electrical engineers in the selection and purchase of new electrical equipment and in the replacement of old apparatus.

The geological department was organized ten years ago as part of the engineering department. Up to that time no systematic geological study of the mine had been made, and the relation between the ore and the folding of the Pre-Cambrian series was not well understood. During the intervening decade the mine has been mapped in detail, and longitudinal- and cross-sections have been drawn. Sketches have been made to aid the mine department. Several hundred prospects in all parts of the United States and Canada have been examined. Many fundamental problems remain to be solved; and to continue this work the department has been reorganized as an independent unit under Donald H. McLaughlin as consulting geologist, reporting directly to the manager and to the president.

The lumber and timber department is under the supervision of W. D. Beradshear, a veteran lumberman. Two separate operations are carried on, one at Nemo, S. D., under the Homestake Mining Company, and the other at Moskee, Wyo., under the Golden Gate Mining & Timber Company, a subsidiary, which furnishes tenoned square-set timber, track ties, shaft guides, shaft timber, lagging, wedges, and blasting poles for the mine, as well as heavy timbers and lumber for general construction.

Each unit has three major phases of operation — (1) lumbering; (2) sawmilling; and (3) transportation to Lead. General-expense items, in addition, comprise the cost of offices and lodging and boarding houses. Logs are hauled to the mill by trucks and tractors, the finished products to Lead by truck. About 17,000,000 ft. b.m. of lumber and timber is produced per year.

The engineering department, under J. D. Johnson, chief engineer, is responsible for general design, cost estimation, and construction of new plant units. In collaboration with the manager and the various departments interested, it collects the necessary data, prepares plans and estimates, and on final approval by the manager it is charged with the carrying out of the plans. This often requires marshaling the available talent and resources of the whole organization.

One group in the department, under Joseph F. Peters, is responsible for

Sawmill plant, Nemo, S. D.

underground surveying and mapping. Another, under A. L. Coolidge, in charge of surface surveying and mapping, supervises the water supply and fire prevention precautions. R. S. Frasier is in charge of drafting.

As an additional activity, the chief engineer acts for the manager in contacting with the operators of the Wyodak Coal & Manufacturing Company, near Gillette, Wyo., a subsidiary of the Homestake Mining Company. The resident manager of this unit is Edward G. Ross.

Under William Frackelton, chief clerk, the general office keeps the financial and cost accounts, collects water rent, administers compensation payment, and the aid fund—the employees' insurance. This office compiles the payrolls, writes checks and drafts for the signature of the general manager, and countersigns them. It issues orders for supplies and equipment, keeps a record of property, and makes out the tax statements. It is the custodian of all records and valuable papers kept in Lead. The head of the general supply department also reports to the chief clerk.

The general supply department, under W. P. Wagner, orders through the general office and receives and checks all incoming and outgoing freight. It receives into its accounts and issues upon requisition all supplies that cannot be charged directly to one operating or constructing account. It keeps accounts of, and restricts in amount as much as possible, the inventory of supplies.

All labor is hired by W. E. Royce, the employment officer, on requisition of the department heads. He keeps records showing age, place of birth, dependents, length of service, dates of hiring and discharge, and other items of interest in the records of all employees.

The hospital department, under Dr. R. B. Fleeger, chief surgeon, gives medical and surgical care to all injured and sick employees and to their families and immediate dependents. This service includes hospitalization where necessary, home calls, obstetrical services, and medicines. No fees are collected from employees. The chief surgeon reports directly to the manager.

The recreation building, under the management of M. C. Kellogg, is a clubhouse built and maintained by the company for its employees and other residents of Lead. It contains a theater that exhibits talking pictures—the only feature for which charge is made. Other features include a fine library, game rooms, billiard tables, bowling alleys, a gymnasium and swimming pool.

Homestake Mining Company was organized in 1877. Five employees have been with us more than 50 years, and a great many have been well over 30 years in service. The scheme of organization is not so important as the men who comprise it; and we feel that we have a group of men whose ability, length of experience, and fine team work will be extremely hard to match.

Safety Assurance and Accident Prevention

The increasing realization of the importance of the safety-first movement in promoting individual happiness and content, and in raising industrial efficiency, is one of the outstanding features in modern industry. Systematic study of causes of accidents has revealed the fact that safe practices can never be attained without whole-hearted cooperation of employer and employee. Coordinated efforts, for the common good, have reduced human pain and misery and are steadily paving the way for better understanding and improved industrial relations. . . . The Homestake company is among the pioneers in this work. Nothing has been left undone to provide safe working conditions and to standardize and perfect equipment so that hazards may be reduced to a minimum. Supervision and training are in the hands of competent officials; and the aid of advisory committees recruited from the mine staff and the workers has been enlisted. Ample rescue equipment is on hand for all emergencies. A bonus system, in effect for several years, offers workmen and foremen tangible reward for effort in preventing accident. In response to these endeavors, the earnest desire of all to perform their duties in the safest possible manner is clearly evident. The splendid morale among the workers is due in large part to the success of welfare and safety programs instituted by the company, and actively supported by every member of the organization.

John R. Treweek
Safety Engineer

Having learned by experience that the safe way is also the most economical way, the Homestake company early realized the value of safety work. Efforts to instil in the men a proper regard for the importance of safe practices have met with gratifying response. From the manager down, every employee is doing his share; each employee has the feeling that his work must be done in the safest possible way, and that safety is of greater importance than speed.

The safety organization consists of a safety engineer; a mine safety engineer; mine rescue and first-aid instructor; a central safety committee of department heads, with the general manager acting as chairman; and a workmen's safety committee, presided over by the safety engineer and composed of men elected for one year.

The safety engineer has general supervision of all safety work and makes regular inspections of all departments in Lead and vicinity, as well as in the outside properties, to eliminate hazards and dangerous practices. He makes a study of accidents and takes immediate steps to prevent recurrence. A mine safety engineer makes daily inspections of all the mines, and offers suggestions to insure safety in underground practice. Regular classes in first aid and mine rescue are conducted twice a week by the mine rescue and first-aid instructor. Instruction in first aid and artificial respiration is given to the men in the electrical department once a month.

Tours of inspection of all mines and surface plants are also made by the workmen's safety committee. This committee reports back to the central safety committee, with which the committee meets every second month for a general discussion of safety and first-aid practice.

A first-aid mine rescue station was built in 1911. From time to time the equipment has been removed and supplemented, so that the station ranks among the first of its kind. It is equipped with twelve units of McCaa breathing apparatus, six all-service masks, six self-rescuers, one M.S.A. motor-driven high-pressure oxygen pump, one carbon-monoxide detector, safety lamps, flashlights, goggles, an adequate supply of cardozide, and spare parts for all equipment. Stretchers, splints, bandages, and other supplies are also available in ample quantities. In addition to a well-filled storeroom, the station has a large lecture and demonstration room, where the regular classes are held, and an office for the mine-rescue and first-aid instructor.

First-aid cabinets and stretchers are conveniently distributed around the

Mine rescue squad

plant and underground. Six main bulletin boards, each having four panels, and several smaller boards of two panels, are placed about the works. These are illuminated by floodlights during the dark hours. Bulletin boards carrying daily news events are also posted about the city. Posters by Elliot Safety Service and the National Safety Council are used. Goggles are furnished to all men requiring them; about 95 per cent of the men underground wear "hard-boiled" hats.

Complete records are kept of all accidents, which are classed as (1) fatal; (2) serious, if time lost exceeds fourteen shifts; and (3) minor, for lay-off's of shorter duration. Nature of the accident, description of the injury, personal details regarding the injured person, and other particulars of interest are included in the record. The injured person is taken to the hospital for medical care and is not permitted to return to work without a release from the doctor. Prompt medical attention is also given to all wounds, however slight they may seem, to prevent infection. Every foreman receives a monthly report giving the number of accidents occurring in his department, and time lost.

At the end of each year since 1923 a bonus of $10 in gold has been given to every underground worker with a record of 300 or more shifts completed during the year without a lost-time accident. Anyone earning this bonus for five successive years receives $20 in gold. The accompanying table gives the number of men, of about 700 employed underground, receiving this reward.

A monthly bonus of $5 is paid to every foreman underground whose crew completes 300 or more shifts without a lost-time accident. A frequency bonus of $10 is paid annually and semiannually to foremen whose crews complete from 300 to 500 shifts per month with a frequency rate below 62.5 injuries per million hours; for 500 shifts or more the frequency bonus is $20. If the severity rate for the year is less than 0.5 shift lost per 1,000 hours worked, a severity bonus of $20 is also awarded. One fatal injury eliminates this reward for the shift foreman and the assistant foreman. Men are also penalized for carelessness and failure to obey safety instructions.

Growth of the Bonus System at Homestake Mining Company

Year	Men Receiving $10	Men Receiving $20
1923	238	—
1924	280	—
1925	275	—
1926	286	—
1927	201	32
1928	190	13
1929	247	9
1930	360	12

Fire lines are run to all timbered mine workings, and standard fire hose is kept in all shaft houses. Cans for carbide and refuse are distributed throughout the mine. Special cars for handling human waste are kept in convenient places underground; sanitary closets and shower baths are available on the surface. Mine ventilation is by natural and mechanical draft. One ventilating shaft with a capacity of 225,000 cu.ft. air per minute is in use at present; a shaft equipped with a fan of the same capacity will be placed in operation in the near future. Compressed air is also blown into the mine workings as needed.

The company is a member of the National Safety Council. Safety-first and mine rescue teams have regularly participated in the national meets, sponsored by the U. S. Bureau of Mines. All safety-first activities at the company's other plants, the coal mines at Wyodak, the lumber camps at Moskee and Nemo, and the Spearfish hydro-electric plant, are under the supervision of the organization at Lead.

The safety-first campaign at the Homestake has lessened fear of accident, injury, and incapacity; and the general morale of the working force has been raised. Reduction in disability and suffering has been accompanied by the development of a spirit of helpful cooperation among all concerned.

Wyodak (Wyo.) coal pit

Plant technique at the Homestake is an example of a combination of metallurgical and chemical methods that have been designed to give maximum technical and economic result. The ore contains a negligible amount of concentratable material, so that flotation or tabling is not indicated to be a desirable step in an effort to isolate the gold or to improverish the ore, which operation, instead, is effected by amalgamation. . . . The presence of much ferrous iron, which if unchanged would have a deleterious effect on the cyanide used as a solvent for the gold, has influenced the decision to retain the practice of milling in water, which practice, incidentally, enhances gold recovery by amalgamation and reduces ultimate residue loss. . . . Cyanicide action is prevented by aëration before the application of cyanide treatment to the two parts of a classified pulp previously ground to a degree permitting maximum net return. The adequate dewatering of slime before cyanidation, by pressure filtration, is an economical and efficient step, the advantages of which deserve wider recognition. . . . The technique developed over many years of successful operation indicates the scientific evolution of a process that has taken into consideration the requirements for chemical precision and metallurgical adequacy in both phases of treatment. These results reflect credit on all who are or who have been associated with a development that has played a major part through many decades in stabilizing and aiding the production of gold in the United States.

Allan J. Clark
Metallurgist

Milling, Amalgamation, Cyaniding

Many articles have been devoted to the metallurgy of Homestake ore. Time has passed; new machines have become available and new methods have required investigation, and, perhaps, adoption; but Homestake ore is unchanged. Methods that were successful in the past are just as sound now. The fundamental requirements for cyanidation, as established in the early years of the century, remain the fundamentals of today. To summarize these: (1) Amalgamation gives favorable results; (2) presence of ferrous compounds in many of the gangue minerals, necessitating careful chemical and mechanical preparation of the tailing, is a dominant factor in determining the methods of cyaniding; (3) the sulphides and arsenosulphides yield their gold readily and at fairly coarse sizes; the non-sulphide minerals yield reluctantly, even when rather finely ground.

Amalgamation of as much as 70 per cent of the gold content is effected readily. Laboratory tests at mill sizes indicate that upward of 75 per cent is free gold, but at present we are satisfied with a mill recovery just above 63 per cent. When this amount has been withdrawn, the remaining free gold, which consists of the finer particles, is almost all recoverable by cyanide solutions of dilutions customarily used, within the time available for treatment.

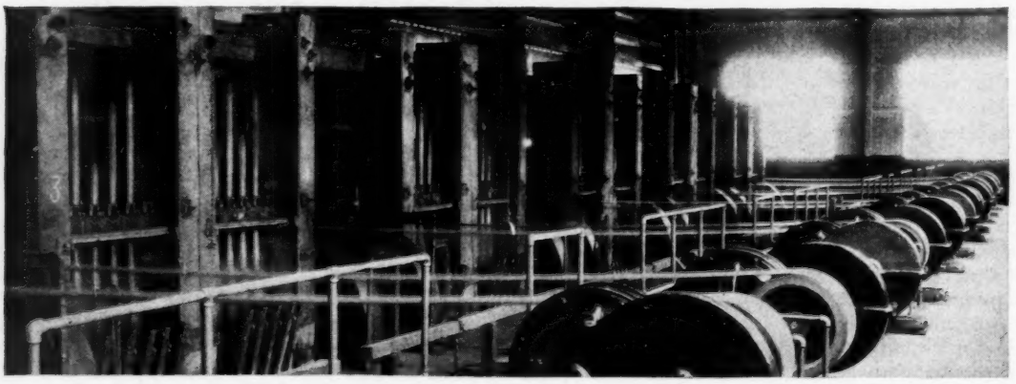
I have said "almost all," for careful laboratory tests almost invariably show a few cents' worth of amalgamable gold present in cyanide plant residues. Indeed, I am in accord with the recent editorial in this publication, which stated that free gold, recovered as amalgam, was 100 per cent recovered, whereas this recovery had never been recorded by cyanidation.

We find further benefits from amalgamation. It is our experience that the cost is less than by any other method; that a unit of gold is amalgamated and marketed for less than it costs to precipitate a similar unit of dissolved gold from cyanide solution, to refine and market it. Impoverishment of the tailing is helpful, as the maximum economic extraction is made from material that is definitely coarser. Overgrinding is minimized. The economies of sand-leaching—and these are real economies—are made possible.

Among the minerals containing iron in the ferrous state are pyrrhotite, chlorite, cummingtonite, and a dolomitic carbonate. Some of these carry as much as 30 per cent Fe. These compounds oxidize rapidly—or perhaps it would be more precise to say steadily, as the action seemingly continues throughout the treatment cycle. In oxidizing, they generate cyanicides and withdraw oxygen from the working solutions. Cyanidation must be applied immediately after comminution; oxygen must be supplied from time to time, to maintain dissolution of the gold; crushing in water, rather than in cyanide solution, is desirable.

The ready solubility of gold from the sulphides, and the less ready solubility of that in the non-sulphides, have an important bearing on the grinding problem. A small fraction of the stamp tailing cannot be taken for further grinding, which must apply to the greater part of the whole, with correspondingly high grinding charges, if even slight additional extraction is to be achieved.

When an enterprise develops over a considerable period of time, as has the Homestake, many conditions arise that are not encountered at what might be called a custom-made mine of the modern era. Some of these conditions may be favorable; many are not. But they are facts. Each new installation is affected, in some measure, by what has gone before; each, in its turn, influences what comes after. Every decision is qualified by some former de-



Motors, gear reducers, stamp mills in the new South mill

vision. The slate is never wiped clean.

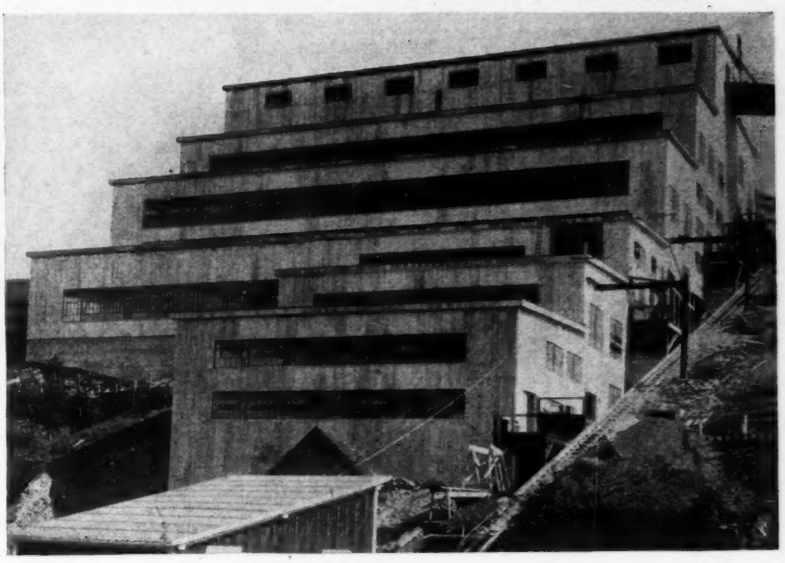
As an example: When the first cyanide unit was planned, the milling plant consisted of six stamp batteries, totaling 1,000 stamps. These were located along the strike of the lode, the extreme being 1½ miles apart, separated by a mountain ridge. The southern group consisted of three mills. Naturally, the tailing from these was brought, by gravity, to a central point, and the sand plant was built there. Later, another plant served, similarly, the northern group. But at this time, the profitable treatment of the low-grade slime seemed improbable, so these first plants were solely for sand treatment. When a slime plant was planned, it had to be constructed at the point of confluence of the two watersheds, about 3 miles from the sand plants and at 300 ft. lower elevation, in order to bring all the slime to a central point. Perhaps this particular item has added little to operating costs other than for maintenance of plants. But the first cost was greater, much machinery was duplicated, and the physical separation prohibited certain interchanges of working solutions that might have been highly beneficial. Similar details in planning at mine and mill might be cited.

Milling commences underground, in three Traylor jaw crushers operating below the 800-ft., 1,400-ft., and 2,000-ft. levels, respectively. The feed in each instance, delivered by Allis-Chalmers apron conveyor, is the oversize of a grizzly with 6-in. spacings. One 125-hp., General Electric motor is belt-connected with each crusher, the output of which is about 250 tons per hour of ore reduced to 6 to 8 in. Crusher discharge joins grizzly undersize and passes through bins, en route to the skips in which it is hoisted to the surface.

At the Ellison hoist the ore is delivered from the skip bins to two 7-ft. Symons cone crushers, one of which is normally in reserve, driven by 250-hp. Allis-Chalmers motors. These, set at 2 in., discharge to Link-Belt conveyors, 42 in. wide, which deliver to a shuttle conveyor for distribution in the storage bin, whence the ore is drawn by 4-ton cars and trammed to the mills.

At the B & M shaft, in addition, two No. 8 Allis-Chalmers gyratories, driven by 70-hp. motors, effect reduction to 4½ in., and four No. 6 units of the same manufacture, driven by 35-hp. motors, crush to 3 in.

In addition to the modern South mill, two of the old mills are still in service. At Terraville, a mile north of Lead, the Pocahontas mill, of 160 stamps, crushes and amalgamates ore that is then cyanided at the No. 2 sand plant. This was formerly known as the Deadwood-Terra mill. Little ore remains in this northern area, and most of the mill feed is transported from Lead, through a tunnel in the hanging wall and now precariously near the moving ground of the open cut. With a future so uncertain, we have not been warranted in adding grinding machinery, and the mill operates almost as it did 30 years ago.



South mill

It is a real antique, yet it shows fair results. The stamps each weigh 900 lb.; they drop 90 times a minute. The depth of discharge is about 9½ in., through No. 146 Rek-Tang screens (aperture 0.024 in.). This screen delivers as coarse a tailing as we care to carry to the sand plant. We try to send low-grade ore and upper-level ore here, the latter because oxidation has made it rather more pervious to cyanide solutions. Costs have been kept down by using the old stamp parts reclaimed from the 600 stamps discontinued in recent years, and by doing a minimum of repair work on the old building. It was at this mill that a ball mill was operated for several years, with unsatisfactory results. Conditions were unfavorable, but they disclosed the machine's limitations. Requirements for successful operation were rigorous and difficult to reconcile with our coarse-crushing problem. This had much to do with the decision to retain gravity stamps in the South mill—a decision amply justified by results.

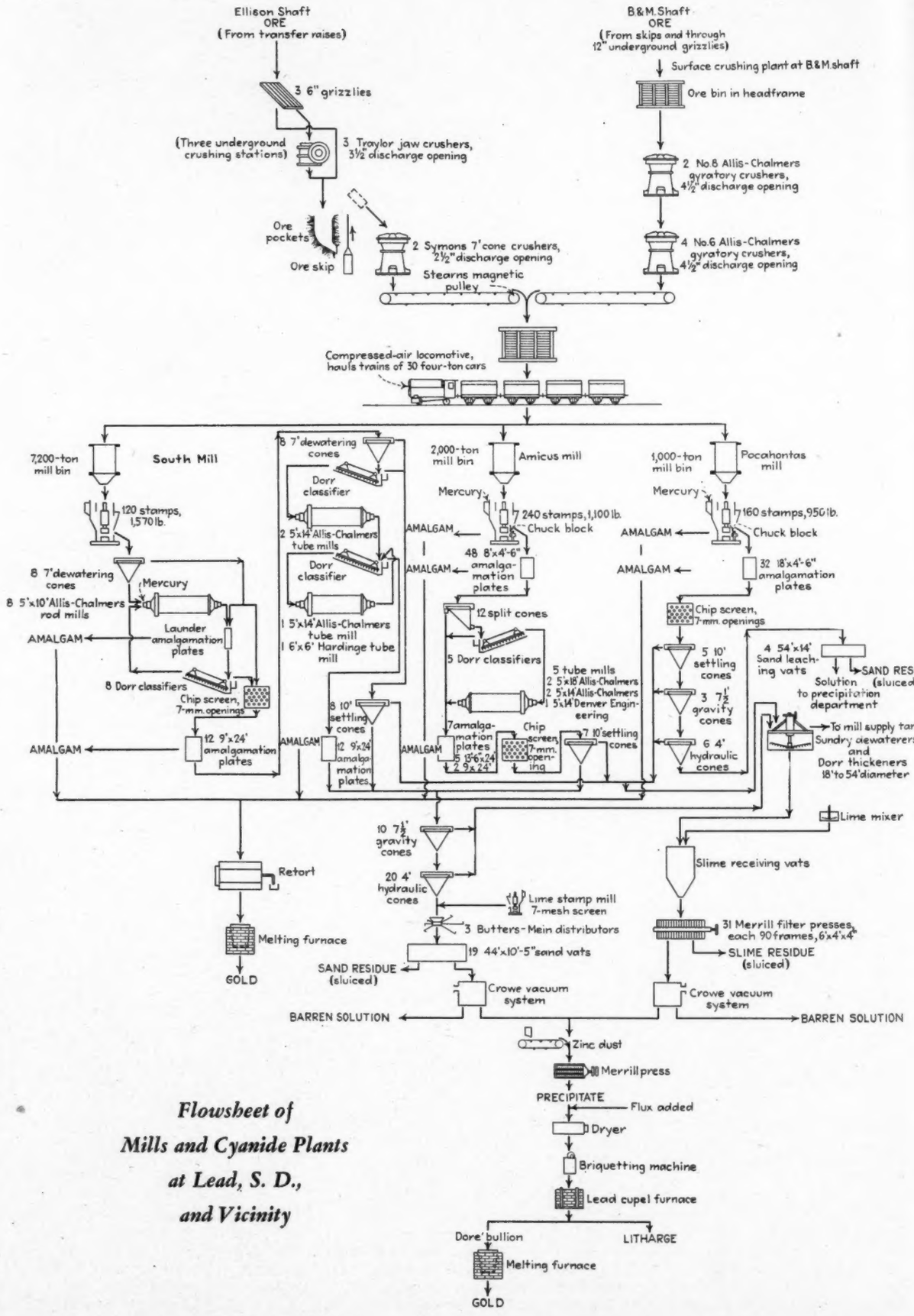
The Amicus mill, at Lead, was the best of the old mills. It has been remodeled, and continues to give fair service. Here the stamps have been weighted up to the capacity of the driving equipment, the falling weight being about 1,100 lb. Inside amalgamation is still practised; the first outside plate, most important in amalgam recovery, has been shortened, and tube mills, fed through split cones from Dorr classifiers, and delivering ground sand to a second row of amalgam plates, complete the flowsheet.

Screens are Rek-Tang No. 110 (aperture 0.044 in.) and No. 674 (aperture 0.030 in.), these being the coarsest that can be used without scouring the outside plate. This limitation of size results in an excess of grinding capacity, so we endeavor to supply this mill with the richer ore, and grind it to a finer final sizing than is sought at the other mills. Fragments of wood recovered from the batteries of these two mills are burned and the ashes sold to smelters. More than $100,000 has been received from this source since 1916.

The South mill, built in 1921, handles 60 per cent of the total tonnage, which amounts to from 3,800 to 4,300 tons per day. In this unit the falling weight of each stamp is 1,570 lb. when newly furnished with shoe. The batteries are arranged in 24 sets of five stamps, which receive ore, by suspended Challenge feeders, from a 7,200-ton bin. Mortar boxes are arranged back to back, but the South mortars are at a higher level than those on the North side, the cam floor of the latter being at the same elevation as the mortar floor of the former.

Each five-stamp camshaft is driven by an independent 25-hp., General Electric, back-geared induction motor. Stamp output, which varies from 15 to 18 tons per 24 hours, is regulated by screen adjustment, the apertures being 0.295, 0.588, 0.713, and 0.838 in. (square). The two intermediate sizes are those most generally used, the objective being the variation of final size of tailing as indicated by the grade and physical properties of the feed. Height of discharge is about 2 in., with a ratio of water to solids of 5.5 to 1. Shoes are from American Manganese Steel; dies are cast locally, of hard white iron; shafts are of hammered iron; stems of mild steel.

We consider that much of the satis-



Flowsheet of Mills and Cyanide Plants at Lead, S. D., and Vicinity

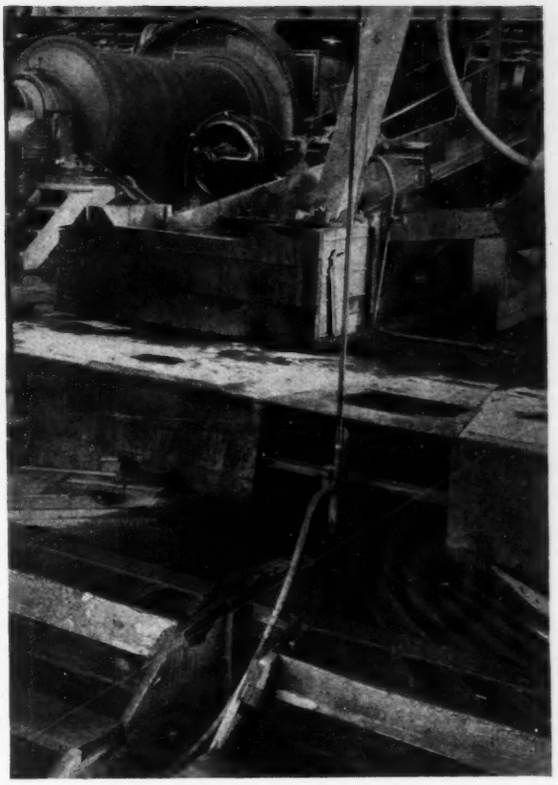
tactory service obtained from these units is due to the mechanical care given them. Unlike the rough-and-ready methods formerly to be noted about stamp mills, we have recognized that these machines require the same attention as to alignment, lubrication, and avoidance of lost motion that would naturally be given to less sturdy devices.

The stamps serve for intermediate reduction between primary crushing and rod and tube milling. Discharge from the batteries passes to eight 65-deg., 7-ft. diameter dewatering cones, the underflow going to the scoop of eight 5x10-ft. Allis-Chalmers rod mills in closed circuit with eight Dorr classifiers, each 4 ft. 6 in.x22 ft. 4 in. A dewatering cone, a rod mill, and a classifier constitute a rigid unit, but a system of sumps and tipples between stamps and cones permits the diversion of the pulp from any battery to any one of three cones, as desired.

Each rod mill has an initial load of about 11 tons of 3-in. rods, of 0.85 to 1 per cent carbon steel. Alloy-steel rods, rods of smaller diameter, and heavier rod loads have all been tried and discarded. The rod mills are driven through herringbone gears, in a single reduction, by 100-hp. Allis-Chalmers motors. The average load is about 75 hp. Shell liners are of hard white iron, locally cast. They last about seven months. End liners are of Allis-Chalmers alloy steel. Those at the feed end last four years; those at the discharge end, but half as long.

As originally designed, six rod mills were provided to grind the pulp from 120 stamps. Later, two additional rod mills were installed, and the stamp duty was increased enough to supply the feed to them. The change, of interest to note, was followed by a slight tapering of the rods at the feed end—a condition not previously observed. Also, the general operation of the mills was rather more satisfactory with the finer feed. The new feed to each mill averages slightly over 200 tons per 24 hours, with a circulating load about twice as much.

Overflow from the rod-mill section passes through a second series of dewatering cones, the underflow of which serves as feed for the fine-grinding section, which comprises three 5x14-ft. Allis-Chalmers tube mills and one 6x6-ft. Hardinge mill, all of which use imported 2½-in. pebbles as grinding media. Liners of the tube mills are of Goodrich rubber—the first set of which served almost five years; white iron; or Belgian silex. Rubber is gradually being adopted as the standard lining, the long life and smooth operation being considered as more than offsetting the rather higher unit cost. Of interest to note, and difficult to understand, is the fact that the rubber-lined mills grind more and use less power.



Rod-mill and classifier section in South mill, with distributors to amalgamation plates

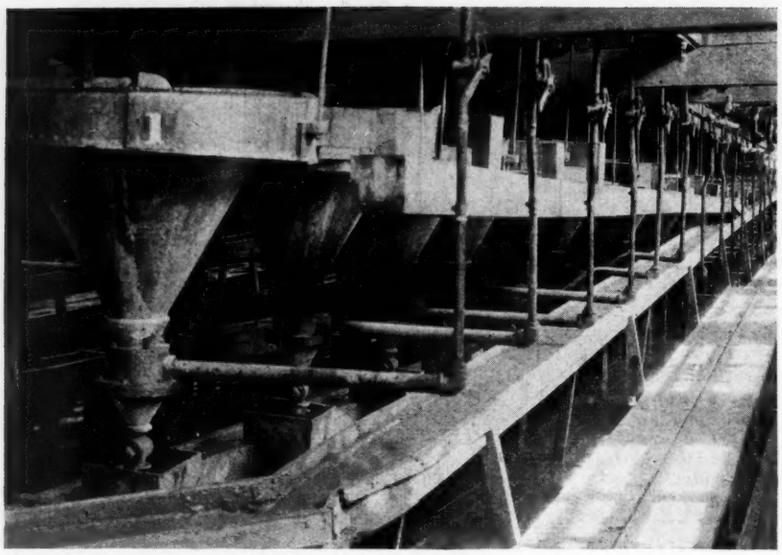
Discharge of the pebble mills passes to Dorr classifiers, producing a rake product that is returned for fine grinding and an overflow that passes forward for metallurgical treatment. Fine grinding effects the release of the gold for amalgamation and cyaniding, and this is the major object of this installation. It also serves as what might be called a plant "governor," smoothing out the irregularities of rod-mill grinding. Overflows of the tube-mill classifiers and of the second group of dewatering cones unite to constitute the mill tailing.

Amalgamation commences in the rod mills, into which quicksilver is periodically fed. The discharge of these mills passes through a screen, for the removal of scrap steel, to an amalgam sump, where it is diluted with a portion of dewatering-cone overflow to a water ratio of about 1 to 1. Most of the coarser gold settles out in this sump. Much of it is thoroughly amalgamated, but some of the larger particles are merely superficially wetted by the quicksilver; so that, although they adhere to other particles, they contain only about 30 per cent of quicksilver, and must be softened by further addition of mercury in the clean-up room. A few coarse particles, from high-grade ore, will flatten out under the pounding of the rods, and will be found in the scrap screen basket, which is always examined for such pieces. These are extremely few, but the fact is noted as being, perhaps, a type of the "hammered gold" stated by Professor Eggleston to be unamalgamable. This sump is cleaned fortnightly, when the mill is shut down, and the classifier, scoop box, and other parts of the circuit are searched for amalgam. The "tie-up" in this circuit is about twice that in the old-style stamp mills using inside amalgamation.

The overflow from the sump passes over plates resting in the bottom of the launder leading to the classifiers. These are renewed every four hours. Overflow from the classifier is distributed over twelve 9x24-ft. composite plates, with a 2-oz. silver plating. In addition, the tube mill discharge passes over a 9x24-ft. plate.

Plates are dressed and cleaned daily. Amalgam is cleaned with quicksilver in Wedgwood mortars and squeezed in a hydraulic press. Skimmings are ground in a 2x3-ft. barrel, steel balls being the grinding media. Quicksilver is added to the barrel, which rotates slowly. The ground sand, discharging through a trunnion, returns to the mill circuit. Cleaned amalgam is transferred daily to the assay office, where the refinery is situated. Gas-fired retorts are used for the treatment of amalgam, producing a sponge that is about 43 per cent of the amalgam charge. Melting is done in coke-fired, natural-draft furnaces.

The net recovery of gold by amalgamation, at the South mill, during 1930, amounted to $2,817,567. About ⅛ oz. troy of quicksilver, costing about $0.0125, was lost per ton treated. Total



Battery of classifying cones

amalgamation costs were less than $0.005 per dollar recovered.

Hydrometallurgical practice at the Homestake takes advantage of the fact that the gravity leaching of many types of gold ores is practicable and effective even after comparatively fine grinding; and that milling in water can be practiced, and its benefits realized, if the dewatering of the aqueous slime pulp, before cyanidation is commenced, is efficiently performed in vacuum or pressure apparatus.

A typically representative screen analysis of a sand charge is as follows: on 50 mesh, 4 per cent; through 50, on 80, 15 per cent; through 80, on 100, 12 per cent; through 100, on 150, 17 per cent; through 150, on 200, 18 per cent; through 200, 34 per cent. The slime treated in the filter presses is 99 per cent minus 200 mesh.

Cone classification effects the separation of sand from slime, each for treatment in its respective plant. The procedure is to effect the classification in three stages, the first close to the stamp mills, the others in the sand plants. Overflow of the first series is clarified at once, the water being available for pumping back to stamp mill or for gravity sluicing of sand charges. The underflow, reducing to a water ratio of about 3.5 to 1., flows in cast-iron pipes to the second series of cones, situated in the sand plants. The final series of cones are equipped with means for providing an upward wash with alkaline water reclaimed from the filling overflow of a previous sand charge.

Cones, made locally, are equipped with removable discharge ends, in which are placed bushings of hard iron, of various diameters, as required. The first cones are from 8 ft. to 10 ft. diameter, with bushings up to 1½ in.; intermediate cones are about 7 ft. diameter; third, or "sizing" cones are 4 ft. diameter, 70-degree slope, with bushings about $\frac{33}{32}$ in. diameter. A signal device indicates chokage.

Leaching of the sandy material is effected in redwood vats. At the No. 2 sand plant are four vats, 55 ft. in diameter by 13 ft. deep. At the No. 1 plant (which is the more important unit, and to which reference is made in what follows) are nineteen vats, 44 ft. in diameter by 10½ ft. effective depth. Each will treat 670 tons of charge. The vats are in three rows, each served by a traveling Butters-Mein distributor. Lime, crushed in a one-stamp battery through a 7-mesh screen, is introduced to the pulp as it discharges from the final set of cones. The bottom of the vat is provided with the usual lattice framework of pine wood, upon which rests coco matting, this, in turn, supporting a cover of 10-oz. canvas duck.

Aero brand cyanide, 49 per cent NaCN equivalent, has displaced the higher-grade salts. It is fed to the strong solution by means of a screw feeder, actuated by a motor-driven train of gears.

Metallurgical practice is determined by the necessity of repeated aëration of the charge to maintain sufficient oxygen in the solutions to effect extraction. Advantage is taken of the opportunity to reduce cyanicides by aëration after milling in water, but before the addition of cyanide solutions.

Aëration in the leaching plant, after deposition of sand in the vat, is by means of low-pressure air, introduced under the coco matting. The pressure is slightly more than the weight of the column of sand; in No. 1 plant, 7 lb. per square inch. The practice necessitates an even distribution of fine material throughout the charge, and the absence of factors that would cause short-circuiting. In other words, it calls for thorough separation of slime from sand, accomplished by the careful classification described, and for rather complete drainage of the charge before application of air.

The lixiviation practice that follows is designed to effect a progressive enrichment of solution before precipitation, the effluent from the latter part of a treatment being strengthened but not precipitated before being returned to the top of another charge. Solution and zinc are conserved by this system. Total solution used amounts to but ½ ton per ton of sand.

The water drainings from the newly filled charge contain sulphates and thiosulphates. After the second aëration, when cyanide solution has been added to the top, these same compounds appear in larger quantity. After a time they are followed by thiocyanates, which, in turn, are followed by the first traces of cyanides. Gold appears in the effluent soon after the first trace of cyanide is noted; at times the interval has been so brief that we have used the ferric chloride test for thiocyanate as a guide to the operatives, this being a sure indication that cyanides might be looked for within a given time. Thiocyanates, the main source of cyanide loss, are stable compounds. They build up in the solutions, but do not affect extraction. Probably about ¼ lb. sulphur is removed from a ton of sand during leaching.

An extremely low alkalinity is favored. High alkalinity retards extraction, perhaps actually prevents the recovery of the last 5 or 10 per cent of soluble gold. Leaching is by gravity pressure. Sluicing is with water at about 10-lb. pressure.

In general, the aim is to maintain the effluent solution of lowest strength at a figure that may be readily precipitated (about 0.035 per cent NaCN) and to add cyanide to the stronger solution in the amount required to insure this

Table I—Leaching Extraction, by Grades, of a Typical Sand Charge

Sands		Weight, Per Cent	Assay		Extraction Per Cent
			Head	Tail	
.....	+50	2.5	$0.91	$0.42	54.0
—50	+80	14.5	0.95	0.36	62.0
—80	+100	11.5	2.35	0.54	77.0
—100	+150	17.0	2.05	0.44	77.0
—150	+200	21.5	2.32	0.42	82.0
—200	.....	33.0	3.85	0.39	90.0
Totals and averages		100.00	$2.50	$0.42	83.2

strength when it has passed through the charge. This ongoing strength is usually 0.08 to 0.09 per cent NaCN. Cyanide consumption is about ¼ lb. NaCN per ton.

The slime from the cones is dewatered in several groups of tanks of miscellaneous size and type, the most favored being two 54-ft. Dorr thickeners. The combined underflow from these units, containing 35 per cent solids, passes by pipe line, at 1½ per cent grade, to the slime plant, over three miles away.

Table II—Per-ton Milling Costs, 1929; Consumption Data, 1930

All Plants	
Crushing	$0.038
Milling	.276
Cyaniding	.189
Total	$0.503
South Mill	
Superintendence	$0.011
Stamps	0.089
Rod mills	0.084
Amalgamating	0.014
Tube mills	0.014
Assaying and refining	0.013
Miscellaneous	0.010
Total	$0.235

In 1930 the costs were adversely affected by the destruction by fire, of the Ellison hoist, which entailed several months of operation at part capacity.

Unit Consumption, 1930	
Mercury, troy ounce, per ton milled	0.128
Cyanide, in terms NaCN, lb. per ton	0.27
Zinc dust-Merrillite, lb. per ton	0.06
Lime, lb. per ton	3.12

Table III—Metallurgical Results for First Six Months of 1931

	Tons Treated	Recovery—Per Ton Milled	Recovery—Per Cent
Amalgamation	697,810	$4.34	62.20
Cyanide treatment of sand	393,462	1.48	21.12
Cyanide treatment of slime	302,519	0.72	10.33
Totals	.....	6.54	93.65
Residues	.....	0.44	6.35
Grade of ore	697,810	6.98	100.00

Slime treatment duplicates sand treatment, so far as the underlying principles are concerned. The periods of drainage, aëration, and leaching; the low alkalinity; the enrichment of solution, before precipitation, by a double passage through the charge, are all practised. The equipment, of course, differs, being adapted to the treatment, under 30-lb. pressure, of material finer than 200 mesh.

Equipment consists of 31 26-ton Merrill presses, of the plate-and-frame type, each press having 90 frames, 6 ft. x 4 ft. x 4 in., the latter dimension being the thickness of the slime cake. These presses are filled, in intermittent sequence, by gravity pressure (30 lb.)—an operation that reduces water content to 27 per cent.

The cakes of slime are first aërated, then leached with solution varying in free cyanide from 0.06 to 0.03 per cent (NaCN). After having been given a water wash, the content of the press is discharged, without opening, by means of a sluicing bar operating through an arc of about 200 deg. This bar traverses the length of the press and discharges water at 70 lb. pressure through nozzles of $\frac{5}{32}$-in. diameter, one nozzle opening into each frame.

Total treatment time ranges from seven to ten hours, depending on whether the charge is a clean, unoxidized slime, or a more colloidal and partly oxidized product. With the former, filling requires about one hour; with the latter, 50 per cent more. Treatment is correspondingly lengthened, the extraction from an oxidized slime beginning later, requiring more time, and being less complete than for unoxidized material. Sluicing, too, is less complete, some slabs of slime adhering to the cloths and reducing the capacity of the press. As the amount of slime so retained varies almost in proportion to the filling time, it can readily be allowed for in estimating plant tonnages.

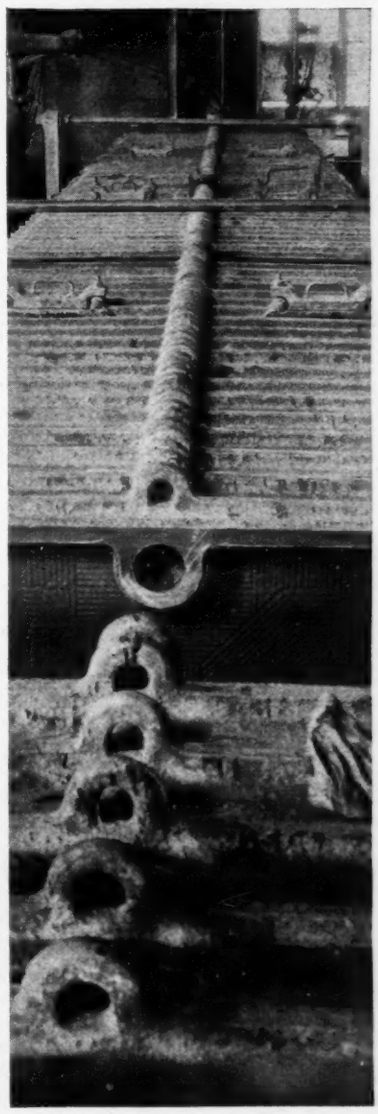
The plates are covered with two superimposed cloths, a light muslin twill, next to the frame, providing a cushion for the No. 10 cotton duck that covers it and preventing the stiffer cloth being forced into the corrugations of the plates. Length of use, ranging from 16 to 30 months, depends largely upon the price of cotton. Perhaps 20 months is long enough for average service with a normal cotton market.

Precipitation at all plants is effected with zinc dust (Merrillite), the Merrill-Crowe process being used. An interesting feature is the addition of a filter aid (Celite) with the precipitant, both materials being fed from a Homestake-type belt feeder, driven by motor. Gardner-Rix vacuum pumps effect the de-aëration of solution, and Aldrich Triplex pumps deliver the mixture of solution and precipitant to 52-in. triangular-frame Merrill precipitation presses. The final pressure is not over 40 lb. Plates are usually clothed with a light cotton cloth, but we are now operating with a so-called sateen, slightly different in weave from the twills previously used.

Duplicate cloths are employed, the outer one, in contact with the precipitant, being burned at each clean-up and the ashes added to the product of the presses, the new cloth being placed next to the frame, and the cloth formerly in that position being moved forward for another month's run. The outside cloth is sometimes painted with a water suspension of Celite, thereby reducing the amount of precipitate adhering to the cloth and so entering the ash.

Sand-plant solutions are naturally clarified in filtering through the sand charges. Slime-plant solutions require clarification, which is effected in two ways. It will be recalled that the so-called weak solution is precipitated, whereas the strong solution is returned, without precipitation, to storage sumps. When a leak develops in a press cloth, the cloudy effluent solution is at once diverted to the strong sump, thus keeping much sediment from the weak solution. The weak solution must still be clarified, however, and this is effected by pumping, with a Gould centrifugal, through a small press of the same type as the slime presses.

The good precipitate is mixed with litharge and borax, hydraulically pressed into 5x4-in. briquets, which are dried and charged onto a lead bath in a gas-fired cupellation furnace, which, at this stage of the process, serves as a reverberatory melting furnace. When the test is full, slag is withdrawn and more briquets are added until all are charged. A tuyère at the back of the



Merrill press

Typical Slime Treatment Cycle

(In Merrill filter presses)

Charge treated July 12, 1931; about 24 tons; gold per ton, $1.80; residue per ton, $0.20; extraction, 88.9 per cent.

No.	OPERATION Description	DURATION Hours	Min.	REMARKS
1	Filling	1	25	Discharge from sludge pressure tank to the presses contains 35 per cent solids. Gage pressure (hydrostatic) 26 lb. Effluent to waste and, in part, to storage for washing.
2	Aërating		30	Gage pressure, 25 lb. Effluent to waste and, in part, to storage for washing.
3	Packing	..	15	Effluent to waste and, in part, to storage for washing.
4	Strong-solution leaching	..	30	Lixiviant: 0.055 per cent (NaCN); $1.14 gold; alkalinity, 14. Gage pressure, 30 lb. Effluent to low-solution sumps, followed by clarification and precipitation. Barren solution used as preliminary wash.
5	Soaking	..	40	Effluent to low-solution sumps, followed by clarification and precipitation. Barren solution used as preliminary wash.
6	Aërating	1	..	Gage pressure, 25 lb. Effluent to weak-solution sumps, followed by clarification and precipitation. Barren solution reused.
7	Stong-solution leaching	..	25	Gage pressure, 30 lb. Effluent to weak-solution sumps, followed by clarification and precipitation. Barren solution reused.
8	Weak-solution leaching	1	15	Lixiviant: 0.02 per cent (NaCN); $0.01 gold; alkalinity 3. Gage pressure, 30 lb. Effluent to weak-solution sumps, followed by clarification and precipitation. Barren solution reused.
9	Low-solution leaching	..	25	Lixiviant: 0.015 per cent (NaCN); $0.01 gold. Gage pressure, 30 lb. Effluent to weak-solution sumps, followed by clarification and precipitation. Barren solution reused.
10	Washing	1	40	Solution displaced during press filling is raised to full cyanide strength in strong-solution sump. Then to storage tanks. Wash effluent to low-solution sump, followed by clarification and precipitation. Barren solution used as preliminary wash.
11	Sluicing	1	5	Gage pressure, 60 lb. Residue pulp to sewer.
	Total	10	10	

test, opposite the working door, is now opened, an air blast turned through it over the surface of the lead, and the resulting litharge is floated to the front of the furnace and withdrawn continuously by cutting away a channel in the front of the test as the level is lowered. The last litharge is coppery. When it is taken off, a slab of gold and silver, usually of about 975 doré fineness, remains in the test, which is now withdrawn from the furnace, the slab being broken into pieces of suitable size, melted in graphite pots, and poured into ingot molds. A small blast furnace treats all slags, mattes, test bottoms, sweepings and other byproducts of the plants, recovering a lead bullion that passes to the next month's clean-up, and a negligible amount of matte, which is marketed at long intervals. Occasionally a batch of precipitate is acid-treated before fluxing, when it apparently contains too much zinc for easy fusion. When this is done, some pulverized coke is added to the flux as a reducing agent. We do not favor direct fusion of precipitate in the blast furnace.

Bibliography—The metallurgy of the Homestake ore has been described at considerable length in a recent publication of the U. S. Bureau of Mines (Information Circular 6408, February, 1931). To this paper frequent reference has been made.

During the more than 50 years of Homestake operation, the more important papers have included the following:

Pre-cyaniding Period—A. J. Bowie, *Trans.* A.I.M.E. Vol. 10, p. 87; "The Father de Smet Mill"; H. O. Hofmann, *Trans.* A.I.M.E. Vol. 17, p. 498; T. A. Rickard, in "The Stamp Milling of Gold Ores."

Period of Cyaniding Development—Described by Charles W. Merrill, designer and first manager of the cyanide plants. A brief outline of the fundamental problems solved during 1898-1906—a metallurgical campaign that won for him the Douglas medal of the A.I.M.E. (*Trans.* A.I.M.E. Vol. 34).

Period of Cyaniding Progress — (1906-20). An exhaustive description of the metallurgy, by Clark and Sharwood, was published in 1912. (*Trans.* Inst. Min. & Met., Vol. 22, 1912) and other articles, less comprehensive, by the same authors (*Trans.* A.I.M.E., Vol. 69, 155) and by Clark (*Trans.* A.I.M.E. 52, 3) and in *Black Hills Engineer,* May, 1926.

Period of Stamp Mill Reconstruction —The South Mill was described by E. H. Robie, *E.&M.J.*, Oct. 9, 1926, and complete details are also to be found in the Bureau of Mines circular to which reference has been made.

Typical Sand Treatment Cycle

(Slow downward lixiviation)

Charge No. 1535; July 7-13, 1931; 654 tons; head assay, $2.51; residue assay, $0.45; extraction, 82.1 per cent. Screen analysis of charge, containing no amorphous material: plus 50 mesh. 4 per cent; plus 80 mesh, 15 per cent; plus 100 mesh, 11 per cent; plus 150 mesh, 17 per cent; plus 200 mesh, 19 per cent; minus 200 mesh, 34 per cent. Circular vats, 44 ft. diameter by 10 ft. 5 in. deep; capacity, 670 tons (dry weight), with a charge 118 in. deep.

No.	OPERATION Description	DURATION Hours	Min.	REMARKS
1	Filling	8	20	Pulp containing 43 per cent solids joins discharge of lime mill and enters water-filled vat through a Butters-Mein distributor. Overflow, after clarification, is reused in classifiers.
2	First draining	15	40	Effluent discharged to sewer.
3	First aërating	14	..	Gage pressure, 6½ lb.; bottom solution valves closed.
4	Strong-solution leaching	16	..	Rate, 1½ in. per hour; strength of solution, 0.09 per cent (NaCN) gold per ton solution, $ 1.94. Displaced moisture to sewer.
5	Second draining	12	..	Effluent to sewer.
6	Second aëration	11	..	Gage pressure, 7 lb.; bottom solution valves closed.
7	Strong-solution leaching	14	..	Rate, 1½ in. per hour; strength of solution, 0.09 per cent (NaCN); gold per ton solution, $2.30. Effluent to low-solution sump, followed by precipitation, and discharge of barren solution to waste.
8	Third draining	10	..	Effluent to weak-solution sump, followed by precipitation; barren solution to storage for reuse.
9	Third aëration	10	..	Gage pressure, 7 lb.; bottom solution valves closed.
10	Weak-solution leaching	12	..	Strength of solution, 0.055 per cent (NaCN); gold per ton solution, $0.01. Effluent to weak-solution sump, followed by precipitation, and discharge of barren solution to storage for reuse.
11	Washing	29	30	Rate, 1½ in. per hour. Effluent during first six hours to weak-solution sump, followed by precipitation and discharge of barren solution to storage for reuse. Effluent during next 21 hours to strong-solution sump for reuse. Effluent during last 2½ hours to low-solution sump, followed by precipitation, and discharge of barren solution to waste. Wash water obtained from cone overflows.
12	Sluicing	1	30	Water from dam reservoir.
	Total	154	..	

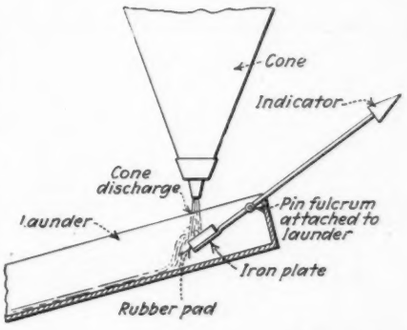
Details of operation of the most economical and most efficient metallurgical plants rarely pay tribute to the zeal and ingenuity of the metallurgical staff in regard to the invention or adoption of labor - saving devices, of recording apparatus that simplifies control, of cost - cutting changes and other evidences of mental alertness and interest in the problems of raising metallurgical extraction and increasing net economic result. . . . A simple change may effect a radical saving. For instance, the length of the shank of a stamp-mill shoe has invariably been "taken for granted" at 5 in. Mr. Hall decided that the top 1 in. was doing no good, so he transferred the amount of metal involved to the wearing part of the shoe, adding to its life and usefulness at no increased cost. . . . Innovations of this character at the Homestake plant have proved well worth while. No feature of this magazine in recent years has met with more approval than have details similar to those described and illustrated in this article.

R. J. Hall
Assistant Metallurgist

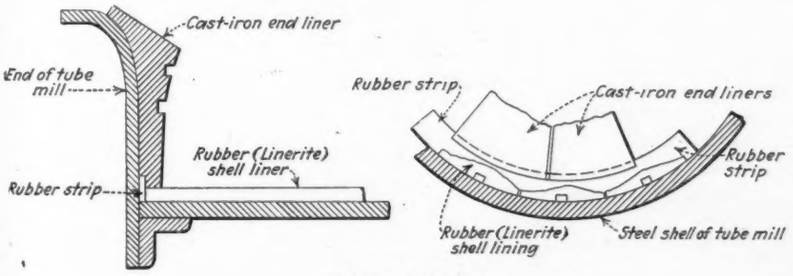
Control and Economy Devices

Rubber is finding increasing application in the mills and cyanide plants of the Homestake company. Goodrich Linerite has been adopted as a standard lining for the tube mills, effecting economies in time lost for renewals and cost per ton milled. The life of such a lining is estimated at five years.

Strips of rubber (2x½ in.) are laid lengthwise at the junction and in a recess in the rod-mill liners. These strips, which effectively prevent abrasion of the shell by pulp that otherwise would work between the liners, outlast two to three sets of cast-iron liners.



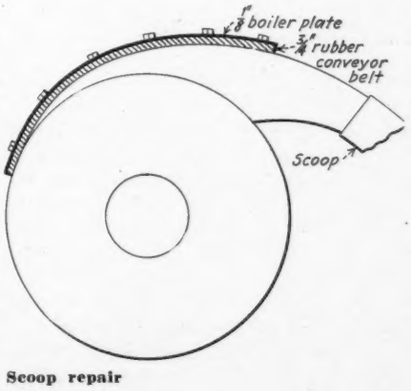
Cone signal



Rubber shell liner

Rubber-faced four-ply belting (⅛ in.) is used for the construction of extra washers under the rod-mill liner-bolt heads. Leakage is thereby prevented.

The classifying cones discharge a highly abrasive pulp onto rubber pads, which outlast four or five replacements of cast-iron or boiler-plate liners of the same thickness. The outer part of the helix of ball- or tube-mill scoop feeders is backed, when worn through, by rubber-faced belting, thereby greatly increasing the life of the part. All scoop feeders are now designed with a flat outer surface, to which the belting and an iron covering plate are attached by studs.

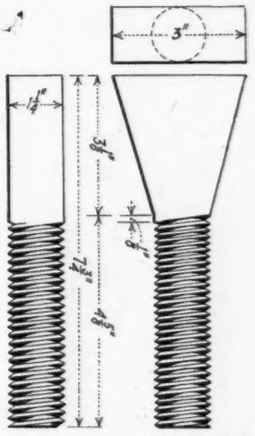


Scoop repair

Rubber baffles are used in sumps to take the force of the inflowing sandy pulp and to effect change of direction of pulp flow in distributing apparatus throughout the mills. Strips of rubber or belting prevent wear of stamp-mill lips and launders, and also serve as cushions under the battery-post shoes and mortar boxes. A rubber paint, known as Covulc, has been found effective in halting wear of classifier bottoms and other metal surfaces.

Rod-mill liner bolts of the rectangular shape shown herewith have been found preferable to those of the square type previously used. The rectangular bolt is held securely until the liner is almost entirely worn away, and the turning of the bolt, when attempt is made to remove the nut—a common experience with the square bolt—is thereby prevented.

Only recently was it realized that the top inch of the 5-in. shank in the ordinary stamp-battery shoe was serving no useful purpose except as an added weight. A new design has standardized all shoes shanks at 4 in., the reclaimed metal being used to increase the length



Liner Bolt

of the shoe proper, adding appreciably to its life at no extra cost. In all the Homestake mills the weight of crushing metal thus added to stamp-battery shoes amounts to about 5,000 lb. per annum.

The trend in stamp-battery screening is back to the square-opening screen. This is because the rectangular opening occasionally permitted the passage of too large a piece of ore, which choked the nozzle of the cones. The cones, as stated, discharge onto a rubber-faced plate, attached to a rod at the end of which is arranged a warning flag. The rod is balanced on a central pin, so that a stoppage of flow from the cone causes the plate to rise and the flag to fall to a warning position.

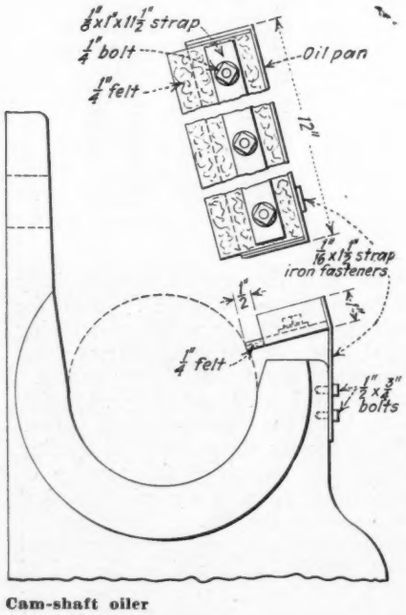
Rods in the cylindrical mills are allowed to wear until they break up, to be discharged with the pulp and to be caught on a screen outside the mill. Effective rod-mill performance, in re-

spect to the efficient utilization of the grinding media, is believed to be largely due to the fact that the feed is not unduly coarse.

Experimental work and plant operation have demonstrated the effectiveness of calcium hypochlorite as an aid in the extraction of gold from ore contaminated with organic matter. Bleaching powder was first used, mixed with the slime pulp en route to the presses. When the operation of this annex to the plant is justified by the character of the ore, the hypochlorite is now made by the interaction of lime and chlorine gas. Liquid chlorine is used to prepare the gas. The technique of gasification and hypochlorite manufacture was devised by N. Herz, chief chemist.

An automatic check on solution tonnage in the slime plant is made by a Telechron electric clock. When the pumps are operating, a branch current line, transformed down to 120 volts, passes through the clock, which stops immediately the pump stops, and starts when pumping is renewed. This arrangement was devised by J. F. Wiggert, chief electrician.

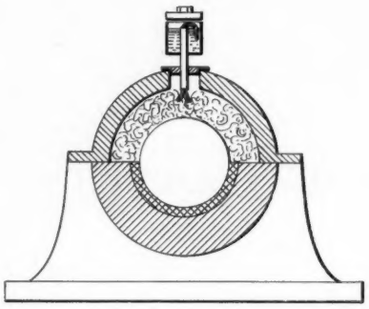
Oil is being used as a lubricant for purposes for which grease was formerly considered most suitable. The result is increased economy and added cleanliness. Camshafts are kept supplied with an adequate film of lubricant by means of a felt pad extending the length of the bearing and contacting with the shaft at an angle of about 15 deg., as shown



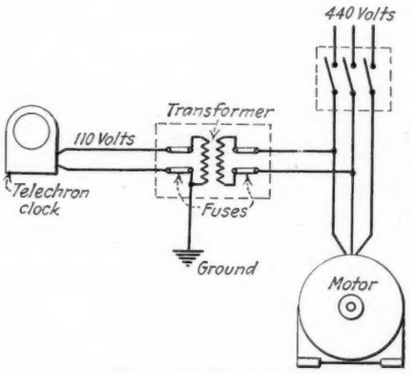
Cam-shaft oiler

in the accompanying sketch. Rod-mill and pebble-mill bearings are supplied with oil by means of a wick of all-wool Germantown yarn, that dips in a one-pint brass reservoir on the bearing cap, and ends in a pad of wool waste, loosely placed between cap and shaft. Perfect lubrication is effected in each instance, attendance is reduced to a minimum, and the consumption of oil in the trunnion bearings of a rod mill is only about half a pint per month. Texaco electric-car oil is used. Four strands of yarn comprise the wick in summer; five, in winter. The packing is prepared by soaking in lubricant previous to use. It is changed every two years.

A feature of amalgamation practice is the success achieved in gold recovery after rod milling by means of a small



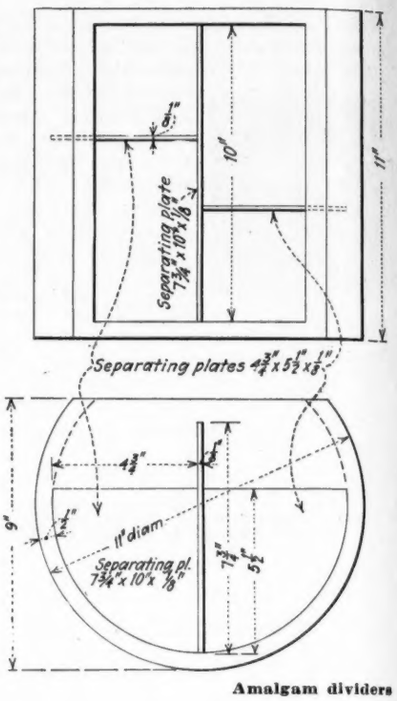
Mill-bearing oiler



Clock pump indicator

plate in the bottom of the launder leading to the classifier that completes the closed circuit. This plate, with an unusually heavy load of amalgam, is removed at 4-hr. intervals and replaced by one already dressed. Storage of the plate under lock and key is practicable, and removal of the amalgam may be delayed until convenient. The amalgam press, of Homestake design, is of the vertical cylindrical type, but with a filtering cloth only at top and bottom—a simplification of obvious advantage.

The customary horizontal, cylindrical amalgam retort is used at the Homestake, with amalgam containers that fit the curvature of the retort. These containers, painted before use with red iron oxide in a water medium, were formerly given a single charge of amalgam briquets. The individual bricks of retorted gold, as usual, ran together, and the large lump resulting had to be broken by hammer into pieces small

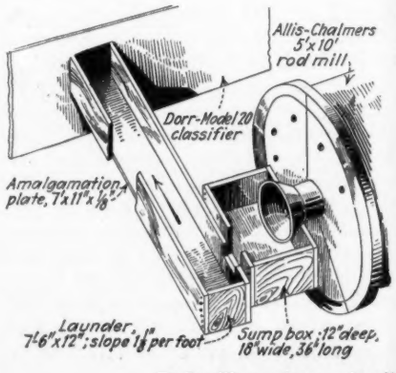


Amalgam dividers

enough to be charged to the melting crucible. This laborious step in the process is now avoided by the provision of division plates of sheet iron, also painted with iron oxide. A single piece placed lengthwise separates the container into two compartments. This piece is held in position during filling by means of light iron guides at each end. Cross-division plates in each of the two compartments are then inserted as required, according to the size of the briquets and crucible requirements.

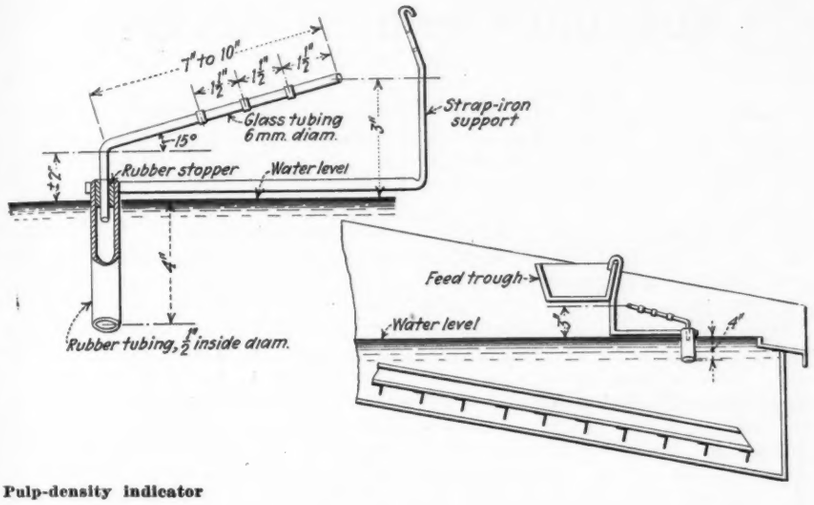
Details of these dividing plates will be found in a sketch shown herewith. Two bars are poured from one charge, so two molds are necessary. These are patterned with only one lug apiece, and are placed in line, with the single lugs at the outer ends. The molds are thus closer together, and the transfer of the gold from one to the other can be effected with less hazard of spilling.

A guide to the density of pulp in the Dorr classifiers is obtained by an in-


Allis-Chalmers 5'x10' rod mill
Dorr-Model 20 classifier
Amalgamation plate, 7'x11"x⅛"
Launder, 7'6"x12"; slope 1" per foot
Sump box; 12" deep, 18" wide, 36" long

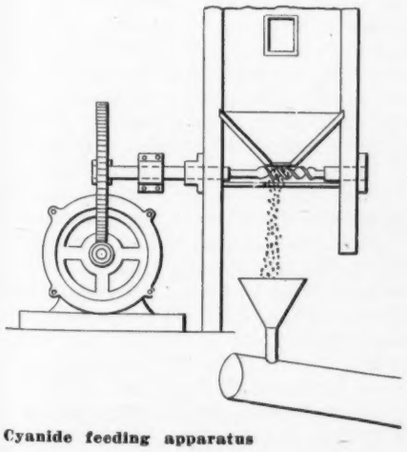
Rod-mill amalgam circuit

genious contrivance developed by Homestake millmen, also pictured herewith, and requiring little explanation. The support for the indicator is of $1\frac{1}{4}$x$\frac{3}{16}$-in. strap iron. One end is hooked over the classifier feed trough; the other is clamped around the rubber stopper of the indicator. The submergence of 4 in. indicated was determined, by experiment, as sufficient to support the water column in the tube, which is graduated at $1\frac{1}{2}$-in. intervals. Agitation produced by the movement of the rakes was found to interfere with the functioning of the apparatus if a greater submergence than 4 in. was adopted. The percentage of solids in pulps of extremely low slime content is gaged by comparison with prepared standards available in sealed tubes, the depth of color being the determining factor.



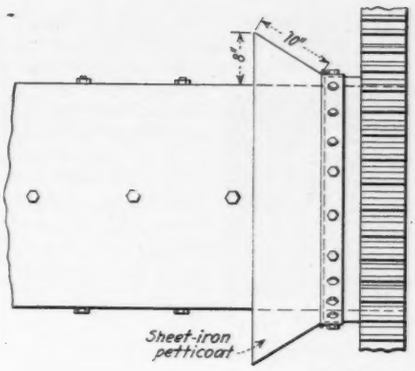
Pulp-density indicator

To avoid the formation of high heat produced when cyanide solutions are brought to strength by the usual method, the mixture is now effected with a large column of water, into which the chemical is fed regularly and slowly by means of an electrically driven apparatus. The hopper containing the cyanide is in the form of a chute, 10 ft. high, 8x8 in. in cross-section, with glass windows at intervals to indicate content. An aperture in the bottom of the chute, which is conical, delivers the cyanide to a screw feeder, constructed of a $1\frac{1}{2}$-in. wood auger with bearings, and driven, at 4 r.p.m., through a gear wheel ($11\frac{1}{2}$ in. diameter, 1 in. face) by a worm gear on the shaft of a $\frac{1}{4}$-in. G. E. motor, 110 volts, 540 r.p.m. The cyanide drops through an aperature in a plate under the screw feeder, as shown, onto a funnel delivering it to the solution pipe leading to a strong-solution sump, and passing, en route, through a screen that retains undissolved cyanide and insoluble débris.



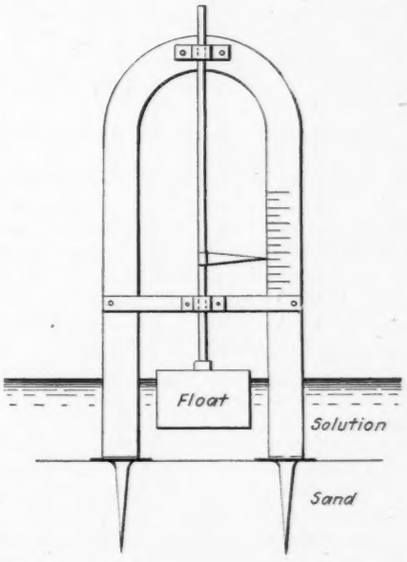
Cyanide feeding apparatus

Rate of percolation of solution through a charge of sand in a leaching vat is checked at intervals by means of a simple float device, calibrated to indicate the drop in level of solution above the charge during a definite period of time. The result is read in inches per hour.

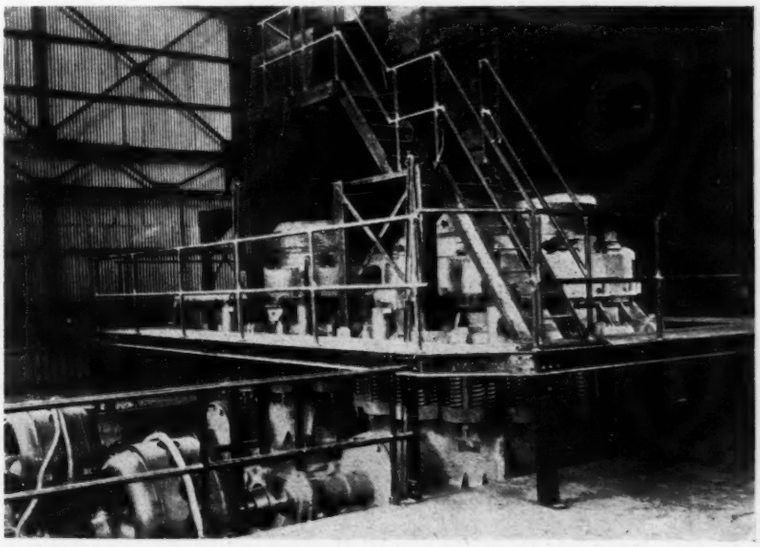


Rod-mill gear protector

Percolation-rate device



Crusher plant at Ellison shaft



The assay office is the "signal tower" of the modern hydro-metallurgical plant. Under the plan in practice at the Homestake, Mr. Herz, the author of this article, is also in charge, under the chief metallurgist, of the operations in the refinery and laboratory, thus providing scope for direct interest and initiative in plant operation. This position was formerly held for many years by Dr. W. J. Sharwood, a frequent contributor to current technical literature, and collaborator, with Mr. Clark, in the preparation of the notable monograph on Homestake metallurgical practice published by the Institution of Mining and Metallurgy in the 1912 volume of its transactions . . . Assayers and chemists will be interested in many features of practice described herewith, such as the dollar-ton system in assaying, and the technique of solution analysis, introduced by Doctor Sharwood. The explanation may be necessary that free cyanide is estimated by direct titration with potassium iodide as indicator, because Homestake solutions are so low in total cyanides and protective alkali that only a negligible interaction occurs, and the net result is not thereby affected.

Nathaniel Herz
Chief Chemist

Fire and Chemical Analysis

In controlling mine and mill operations at the Homestake, about 400 fire assays are performed daily. In addition, many colorimetric gold assays, screen sizings, solution titrations, and other tests are made regularly. Chemical analyses and more elaborate metallurgical tests are conducted at irregular intervals, depending upon operating conditions and results that may be desired.

The greater part of the assaying is done in the assay office centrally located in Lead, but the slime plant at Deadwood has a small one-man assay office. The Lead office is equipped with three natural-gas-muffle furnaces, using carborundum muffles of 8x12½x21 in. outside dimensions. A furnace can be constructed in ample time to replace one in need of rebuilding.

The main furnace room also contains the equipment for parting buttons and for assaying solutions, as well as an elevator for samples and supplies. Drying, crushing, pulp weighing, and gold weighing are each done in separate, adjoining rooms constructed of glass partitions. The hot plates for parting and drying, as well as those for assaying solution, are heated by natural gas. Crushing equipment consists of a Sturtevant roll-jaw sample crusher, a Gates sample grinder, two Braun pulverizers and the customary riffles, screens, and other equipment. A spare machine of each type is available to replace one requiring repairs. The various machines are equipped with hoods connected with an exhaust fan to remove dust. All machines are cleaned by means of air "guns" after each sample has been reduced.

Mine samples taken during the day are delivered in the late afternoon, and assayed the next day. Night-shift samples, and mill and cyanide-plant samples, are received in the morning and assayed the same day. Ore and pulp samples are weighed on a Thomson balance, and stock fluxes are used. For mine samples, an adjustment of flux is made by adding flour or niter, and iron in the form of brads, as required. Gold weighing is done on a Keller balance.

Cyanide solutions are assayed by a modification of the Chiddey method, scorifying the lead sponge obtained by precipitation with zinc dust and lead acetate.

As the product shipped is gold bullion, sold to the United States Mint for $20.6718+ per troy ounce of contained gold, all assays are reported on this basis, in dollars and cents per ton rather than in ounces. To simplify calculations, the assay-ton system has been discarded, and a factor-weight we call the dollar-ton has been substituted. This weight is 30.1464 grams, instead of the 29.1667 gram assay-ton, the ratio between the two being 20.6718:20. One milligram of gold from one dollar-ton represents $20 per ton, with gold at $20.6718+ per ounce.

The greater part of the mill sampling is done by hand at regular intervals, using slotted samplers that take uniform cuts across the pulp streams. Mechanical samplers have been tried at some points, but, for the most important samples, such as sand-plant charges, hand-operated cars carrying a sampler and bucket across the stream have been found most satisfactory. Sand residue is sampled with a slotted pipe driven to the bottom of the vat at various points. The samples from one vat are then combined in a long trough, and portions representing the top, middle, and bottom third of each vat are cut out with a trowel. Slime is sampled with a dipper. The samples are dewatered in a small horizontal press by compressed air before drying for assay.

Mill products are sampled daily, as a rule; a few of the more important samples are taken by shifts. Sand charges and residues are sampled by individual vats, as treated; slime charges are sampled daily, each sample being a composite of portions taken from each press charge as filled. Slime residues are sampled as requirements vary, by shifts at times, or by units of ten or eleven presses, or by leaching rates or other press characteristics. Pregnant and barren solutions are sampled by drip systems. Each tank of solution at the sand plants is sampled as precipitated; daily samples of pregnant solution are taken at the slime plant, the barren solution being sampled each shift.

A precipitate sample, obtained by tryer, is weighed and dried to determine moisture. The dry sample is then ground in a Wedgwood mortar and assayed in quadruplicate, using 0.05 assay-ton portions. Assay slag and cupel are re-assayed with a special flux, and the resulting beads added to the original ones. The combined beads are weighed, then inquarted and parted with proof assays in the same manner as are the bullion samples.

Bullion bars are sampled by drilling two diagonally opposite corners with an air drill, giving a top and bottom sample; 500 milligrams of each portion are weighed out in duplicate, one set being cupelled with 6 grams of lead foil, and the duplicates inquarted by cupellation with silver for parting. The silver-to-gold ratio desired is 2½:1. Runs up to sixteen are made in each case, each run containing two proofs. Parting is done by the standard method in a platinum beaker containing a platinum basket with sixteen thimbles.

Other refinery products—such as blast-furnace slag, matte, and lead—are sample by standard methods and assayed as well as analyzed chemically when necessary.

Another important duty of the assayers is the making of numerous sizing tests, all on dried samples. Many samples are sized daily, including cone overflows and discharges, classifier products, tube-mill feeds and discharges, sands and slimes. All except the slimes are screened on a Rotap machine, using 50-, 80-, 100-, 150-, and 200-mesh screens. Slime is screened by hand, using 100- and 200-mesh screens only. The minus-200 mesh portion is further separated into granular and flocculent portions with a small hand centrifuge. These regular sizing tests are of great value in obtaining uniformly consistent grinding and classification results. Finer screens have been used at times on a small scale, but a screen such as 300 mesh is expensive and difficult to

use, giving little information of value in treating Homestake ore.

Water-to-slime ratios are determined by hydrometers with a scale range of 1 to 1.4, using a table based on the specific gravity of Homestake ore, which is 3. For determining water ratio of coarser products such as tube-mill feed and discharge, a 1-liter galvanized-iron flask is used, the net weight of pulp in kilograms being the pulp density. The flask has a slotted neck, so it is a combined sampler and weighing flask.

Leaching rates at the sand plants are determined at the end of each solution period by means of a float and scale. Rate of fall is measured in inches per hour, with no new solution being added and the bottom-discharge valve being wide open. In the slime plant the leaching rate is an empirical figure, being the seconds required to fill a 5-gal. measure while washing the press charge with wash water at 30-lb. pressure. This rate determines the treatment of the next charge in the same press, and is thus determined for each charge; it is affected by the condition of the press as well as variations in the character of the slime.

Determinations of water ratio and leaching rates are made by the men on shift. Other determinations made regularly by the cyanide-plant operators include colorimetric gold assays of precipitation-press effluents and all titrations of cyanide-plant solutions.

The colorimetric gold assay used is a modification of the Dowsett method, depending on precipitation in a bottle by violent agitation with a little zinc dust in the presence of a very little lead salt and much cyanide. The resulting coagulated precipitate is treated with hydrochloric acid and a little nitric acid, concentrated, and the gold estimated by color after conversion to Purple of Cassius with stannous chloride. At one time a cold-agitation method was devised to replace the Chiddey method for regular daily assays, but was found to be too sensitive to slight variations in quantities of reagents and details of manipulation to be dependable; although, with sufficient care, results were accurate.

The titrations regularly run on the cyanide plant solutions are free cyanide, total alkalinity, and reducing power. Details are given in Table II. Cyanide and alkalinity are titrated in ¾x7-in. Pyrex test tubes; reducing power, in 100-cc. beakers.

In sand treatment, the first trace of cyanide in the effluent is detected by testing 100-cc. samples at intervals with a little potassium iodide and one drop of 0.05N silver nitrate solution. Absence of turbidity indicates the presence of a trace of cyanide.

Estimation of slime in slightly turbid thickener overflows, when such a condition does occur, is performed by comparing a small portion in a test tube with a series of standards made up of the same type of slime sealed into similar tubes. It was found that any attempt to estimate this slime without comparison with standards led to considerable error, the quantity invariably being overestimated.

In addition to the regular determinations and tests, many tests are made occasionally as conditions warrant. Amalgamation tests are made by rather violent agitation in bottles with about 1 oz. of mercury, using samples of 100 to 300 grams, with 1½ parts of water. The sample is panned from the mercury, which is dissolved in nitric acid, the remaining gold filtered off and assayed by scorification. Cyanide tests are made by percolation or agitation; various types of percolators, agitators, and filters are on hand for use as required.

Another useful test is the grading test. This is occasionally made on sand charge and residue samples. It involves the screen sizing of 10,000 or more grams, so as to obtain enough of each fraction for accurate assay. This has occasionally been supplemented by hand concentration of the various sizes. Owing to the presence of heavy minerals in the gangue, the panning is difficult and the separation not all that might be desired. Still, for many years the information thus obtained has been useful, and the best that could be obtained. Lately, much more satisfactory results have been obtained by flotation in a laboratory Janney machine.

In addition to equipment for the testing of ores, a well-equipped chemical laboratory is maintained. Little work of a routine nature is required, but facilities are at hand for almost any analytical investigation. Among the tests made are analyses of cyanide shipments; tests determining metallic and oxide zinc in zinc dust, impurities if present in any quantity; and a test for precipitating efficiency, by means of a standard silver cyanide solution. Lime is occasionally tested, by titration of free lime dissolved in a solution of sugar.

At times other investigations are made, such as analyses of minerals present in the ore. Working solutions, precipitates, and other mill products may be analyzed completely, or certain constituents may be determined at regular intervals over a period of time.

Water treatment for boiler feed is checked regularly. Coals, oils, and explosives are analyzed or tested as occasion may require. Equipment is available for the analysis of iron, steel, and other alloys when desired. In brief, the laboratory is maintained to take care of any necessary determinations that may arise in connection with all operations or in the purchase of supplies, as well as for metallurgical control and research on current technical problems.

Table I—Homestake Assay Data

Samples	Number of Assays	Weight Per Assay Dollar-Ton	Crucible Size, Grams
Mine: Grab, face, pile, car, and test-hole samples	2	½	12
Mine: Moil, diamond-drill sludge and core, special samples	2	1	20
Stamp mill and other mill and classifier products	2	1½	35
Sand and slime charges	3	1½	35
Sand residues; three samples per tank each	2	2	35
Slime residues	4	2	35
Barren solutions	1	20	Scorified
Pregnant solutions	2	10	Scorified
All other solutions	1	10	Scorified

Table II—Homestake Solution Testing Methods

Sought	Sample	Reagent	Indicator or Neutralizer	Result
Free NaCN	20 cc.	$AgNO_3$, 0.05N	KI	1 cc. = 0.025% NaCN[1]
Total alkalinity	20 cc.	H_2SO_4, 0.2N	Phenolphthalein	1 cc. = 10 points[2]
Reducing power	10 cc.	$KMnO_4$, 0.1N	H_2SO_4 in excess	1 cc. = 10 points[3]

Note 1—This represents commercial NaCN, 98 per cent pure, as 1 cc. 0.05N $AgNO_3$ is equivalent to 0.0245 per cent pure NaCN. Aero Brand cyanide is about 49 per cent NaCN, so weights calculated for strengthening solutions are doubled. (2) One point equals 0.0028 per cent CaO, or 0.005 per cent commercial cyanide. Protective alkalinity equals total alkalinity minus 2 points for each 0.01 per cent NaCN (3) One point equals 0.00135 per cent NaCNS. The reducing power is an indication of the power of the ore to consume cyanide and oxygen. Reducing compounds other than sulphocyanide are present in the solutions in very small amounts. Sulphocyanide has at times reached 0.5 per cent.

Duties of the chief engineer of the Homestake company are many and varied, ranging from responsibility for the selection of appropriate prime-mover equipment and the general design of new units to that of acting as technical liaison officer between the manager at Lead and the operators of a subsidiary concern, the Wyodak Coal & Manufacturing Company, which supplies fuel for Homestake boilers and functions also as a coal-selling concern. The history of the Homestake company is a record of continuous adaptation of local natural resources to the needs of an increasing demand for power. A simplification of technique and significant economies resulted from the wider use of electricity; and the continuous nature of operations in mine, mill, and cyanide plants necessitated attention to factors unrecognized in the early days. Prime-mover plant and practice now offer assurance of the provision of regular power. The extremes of climatic variation in South Dakota are met by a nice adjustment of hydro-electric power generation and boiler-coal production.

J. D. Johnson
Chief Engineer

Prime-Mover Plant and Practice

The Homestake Mining Company first required power in 1878, when a mill of 80 stamps was erected. The nearest railroad connections were at Sidney, Neb.; Cheyenne, Wyo.; and Bismark, N. D. Mine supplies were hauled from these points by bull teams, through unfriendly Indian country. These conditions involved dependence for fuel on Black Hills timber, abundant and close to the mine. The early prime movers were therefore steam engines, with boilers burning wood as fuel. Railroads were being built as the near-by supply of timber was being exhausted, and when the cost of wood became excessive—because of length of haul distances—coal was substituted. This extended the period of economical operation of the original mills until 1906, when a hydro-electric plant was built at Englewood, and used at first to operate two of the smaller mills at which rehandling of fuel and antiquated machinery made power costs excessive.

The next six years represented a period of experimentation with electric power as applied to mining and milling, with the trend indicated by the fact that all new equipment installed from this date was electrically driven, with the exception of the steam hoist at the B. & M. shaft (named after Homestake pioneers). The slime plant was changed to electric power during this period; and a third mill of 160 stamps and the two sand plants were equipped with electric drives.

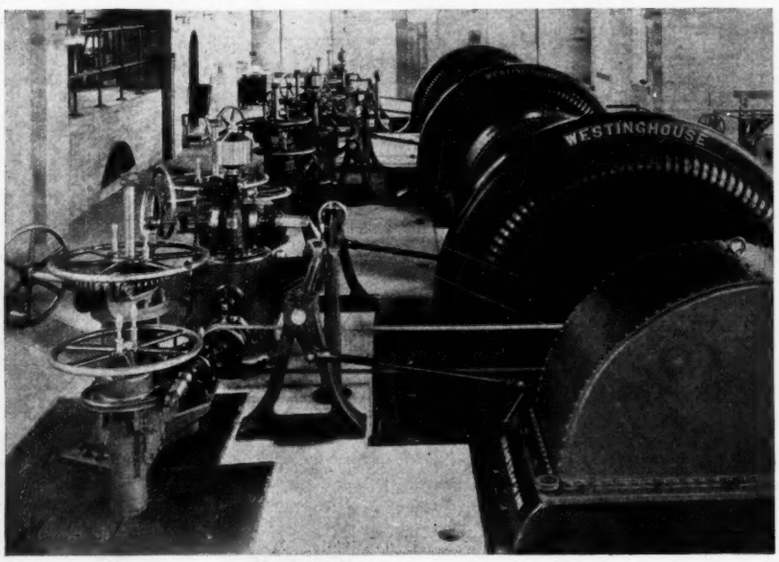
In 1912 the Spearfish hydro-electric plant, No. 1, was placed in operation; in 1916, the steam-turbine plant, and in 1918, the second hydro-electric plant. Coal lands were acquired near Gillette, Wyo., in 1921, and in 1929 the plant there was electrically equipped and a generating unit added to furnish power and light for the city of Gillette. The old Ellison steam-driven cage hoist at Lead is now being replaced with a larger electric hoist for deeper mining, and an additional turbine is being installed in the Lead system plant mainly as a stand-by, but also to furnish additional power when required.

The water supply for the hydro-electric plants originates in springs in Spearfish Canyon, about 12 miles from Lead, below which is the intake for a 28-in. vitrified-tile pipe line that supplies water for milling operations and for domestic purposes in Lead and Deadwood. This line passes through nine tunnels and across one steel bridge, down the canyon of Spearfish Creek, and then back the East Fork of the Spearfish to the Hanna pumping station, equipped with five three-stage Jeansville motor-driven pumps. Three of these are of 2,000 g.p.m. capacity with 10-in. discharge; one is of 1,000 g.p.m. with an 8-in. discharge, and one of 500 g.p.m. and a 5-in. discharge.

The pumps discharge into an 18-in. header leading to a 16-in. line, 1,520 ft. long, which discharges into a sump above the plant. An auxiliary 8-in. line parallels the 16-in. line connecting the sump with the 500- and the 1,000-g.p.m. pumps only. Three pumps are used ordinarily to deliver into the 16-in. line. Gage-register discharge head is 412 ft.

A 30-in. tile line carries this water across a flat on top of the hill to another sump, where it is joined with a 12-in. line from the Rapid Creek ditch and a 16-in. line from the Peake ditch. The outlet from this sump is a 28-in. spiral-riveted steel pressure pipe for 8,350 ft., then being reduced to a 26-in. pipe of the same construction for 8,375 ft. to the Englewood power plant. A low-pressure line also supplies water for this plant, utilizing the flow from the Little Elk ditch, which is picked up at a much lower elevation. The static head in the high-pressure line, 485 ft. at the plant, drives an overhung impulse water wheel connected to a three-phase 60-cycle, 11,000-volt generator. The power generated varies between 300 and 400 kw., which is almost sufficient to run the pumps at the Hanna pumping station. After passing the power plant the water is chlorinated and then enters a 30-in. tile line, continuing to the reservoirs above Lead, from which points it is distributed for milling operations and domestic use.

The surplus water from the springs flows down the main Spearfish Creek to Savoy, where a diversion dam supplies a 52-in. woodstave pipe line with water for the No. 2 hydro-electric plant at



Spearfish hydro-electric plant

Maurice. This pipe line is 4.7 miles long. The water is carried down to the plant under a 548-ft. head through two penstocks, the upper sections of which are of 34-in. spiral-riveted steel pipe and the lower sections of 30-in. lap-welded steel pipe with steel flange joints.

The station equipment at the No. 2 plant consists of two three-phase, 60-cycle, 400-r.p.m., 2,200 volt, 2,000 kva. generators, each driven by two 1,500-hp. overhung impulse water wheels.

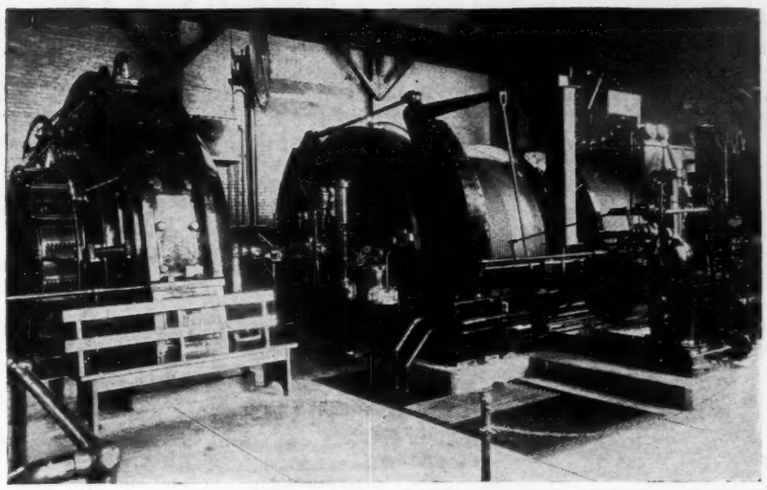
Leaving the No. 2 plant the water enters the creek with the overflow from the dam at Savoy, from which it is again diverted into a 4½-mile tunnel. It is then siphoned across a ravine through two 48-in. wood-stave pipes, 1,200 ft. long, discharging into a steel header upon which are four 36-in. standpipes 54 ft. high. From this point the water is carried down to the No. 1 hydro-electric plant at Spearfish, through two pressure pipes 4,800 ft. long. The upper sections of these pipes are 34 in. in diameter and spiral-riveted, with rubber-packed slip joints, and the same for the middle sections, except that the diameters are 32 in. The lower sections are of 30-in. lap-welded steel pipe, with bolted steel flange joints. The static head of the water at this plant is 667 ft. Station equipment at the No. 1 plant is the same as for the No. 2. Generator voltage is raised to 33,000 volts for transmission to Lead.

All generating stations transmit their power to a substation in Lead, the control center for all power used at the Homestake, and also connected with the system of the Consolidated Power & Light Company. This substation is equipped with the necessary transformers, switchboards, switch controls, relays, and meters for distributing power to the various operations.

The steam turbine plant operates as an auxiliary to the hydro-electric plants, the water supply varying considerably in volume during the year. In the spring and summer periods, when the stream flow is high, the greater portions of the load are carried by the hydro-electric plants, with the turbine plant carrying the greater portions during the remainder of the year.

The turbine plant, adjacent to the substation and above the boiler plant in Lead, is equipped with two 1,800-kw. 3,600-r.p.m. turbines, each connected to a 1,500-kva. 2,300-volt generator. One 5,000-kw., 3,600-r.p.m. turbine is now being installed, connected to a 6,250-kva., 2,300-volt generator. Steam is supplied to the present turbines at 150-lb. pressure, 75-deg. superheat. Each turbine exhausts into a Westinghouse-Leblanc jet condenser. Condenser water is pumped to two Nordberg natural-draft cooling towers.

Equipment at the central steam plant at Lead consists of six Edgemoore, "four-pass" horizontal, water-tube, 600-hp. boilers, equipped with Golden-Anderson automatic non-return steam valves, Foster superheaters, and Greene incline-type "K" chain-grate stokers. Water for the boilers is treated in a Kennicott purifier. Steam from the boilers is conveyed to the turbine plant through a 12-in. wrought-iron pipe, 400 ft. long, laid in a concrete-lined tunnel with a grade of 0.72 per cent toward the boilers. It enters the turbine plant through a vertical shaft from the tunnel.



Electric hoist, Ellison shaft

Coal, delivered from the Chicago, Burlington & Quincy Railroad into a concrete storage bin on the Ellison side of Gold Run Gulch, is carried across the gulch to the bins at the boilers on a 16-in. belt conveyor 750 ft. long, 200 ft. of which runs in a concrete-lined tunnel, a steel trestle carrying it the remaining distance. A storage bin for domestic coal and outlying hand-fired plants of the company is located beneath this trestle, above which is a Hum-mer screen. The supply for this bin is replenished as required by diverting coal on its way to the central steam plant, across the Hum-mer screen, which takes out the larger lumps and deposits them in the bin, the screenings continuing on to the boiler plant. Distribution from the bin is made by truck.

Coal is supplied by the company's own mine, 6 miles east of Gillette, Wyo. The vein is a good grade of sub-bituminous coal, 90 ft. thick with about 25 ft. of overburden. It is estimated that 24,000,000 tons of coal is available on the company's holdings. About 70,000 tons of coal is mined annually, of which the company consumes about 35,000 tons.

Stripping of the clay and sand overburden is done by two hydraulic monitors. The surface water draining into the pit is collected in a sump below the coal bed. Two 600-gal. pumps, with 200-ft. head, pump the water through 6-in. pipes to two 6-in. monitors on the top of the coal bed. The overburden is washed down to a sump in the top of the coal, where a 6-in. Georgia Iron Works gravel pump removes it to the tailing dump through an 8-in. pipe.

After stripping, a No. 2 diamond-drill outfit, working on top of the coal bed, drills holes 4 in. in diameter, spaced 20 ft. apart and 20 ft. back from the face, to a depth of 70 ft. Stellite is used in the bits. One bit drills an average of 300 ft. before resetting is required, and the daily average of drilling footage is about 45 ft., though under ideal conditions one hole per day has been drilled. The holes are drilled during the summer and plugged to be blasted as required.

The 20-ft. layer of coal left temporarily in the bottom provides a safe working footing for the 1½ yd., Model 37, Marion steam shovel, equipped with a 50-ft. boom and clamshell bucket, which loads the coal on a 40-in. drag conveyor running down the center of the pit. The conveyor is extended as required to working distance from the face, which is 200 ft. wide. This conveyor discharges on a 40-in. rubber belt conveyor 700 ft. long, which takes the coal from the pit to the tipple above the railroad tracks. The 20-ft. bottom is mined out behind the shovel.

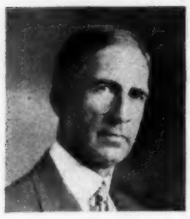
In the tipple the coal is screened to produce commercial coal in the sizes 1, 1½, 2½, and 9 in., respectively. The oversize is crushed in a 32x36, double-roll, Link-Belt, by-pass crusher, and returned to the head of the screen. Three box-car loaders handle the commercial coal, and the screenings fall directly into gondolas for shipment, or to a drag conveyor which supplies the local boiler plant and storage bins.

In the boiler plant at the coal mine are two 250-hp. bent-tube, four-drum Connelly boilers, equipped with Detroit end-dump stokers. The power-plant equipment consists of two Allis-Chalmers turbines, one of 500-kva. and one of 1,000-kva., operating at 175-lb. pressure, without superheating of the steam.

Auxiliary Fuel

Natural Gas at the Homestake

Pipe lines from every important natural-gas field in the United States bring to industry an ideal fuel. Neither distance between wells and market, nor rough topography and high mountains, restrains this important engineering development. One can almost predict that within a few years this source of heat and power will be available in almost every mining district in the country. It will play an important part in underground and surface work, bringing to mine and smelter many opportunities for lower costs, cleaner operations, and exact control in those instances where temperatures must be held within narrow limits . . . The Homestake was one of the first large Western mining properties to substitute natural gas for oil in its shops and assay offices. The following account, by the consulting engineer of the utility company supplying this commodity, gives many details of locally designed apparatus for efficient application, and also comparative costs. Opportunity for the use of gas in drill-sharpening work is especially attractive because of the excellent results achieved at the Homestake and the release in this article of engineering information.



Bancroft Gore

Department of Metallurgy,
South Dakota School of Mines,
Rapid City, S. D.

Natural gas became available to the various communities of the Black Hills of South Dakota in the fall of 1928 through the enterprise of the Montana-Dakota Power Company, a subsidiary of the Minnesota Northern Power Company, with general offices at Minneapolis, Minn. This company controls by direct ownership and long-time leases the best part of the Glendive-Baker structure—a series of domes in southeastern Montana and the extreme northwestern corner of South Dakota. Gas is being produced for more than 70 miles along this great structure which extends in a southeasterly direction from the Ash Creek dome on the north to the Little Beaver dome on the south, the present open-flow capacity of all wells connected to the system being in excess of 600,000,000 cu.ft. of gas daily.

From Baker, the center of the proven gas area, a 12-in. main transmission line, 130 miles long, delivers gas at a pressure from 180 to 250 lb., depending on the seasonal load, to the junction at Whitewood, S. D. From this point an 8-in. branch line 10.5 miles long serves Deadwood, reduced to 6 in. for Central City and Lead. This branch line from Whitewood to Lead, of 13.8 miles, has an average ascent of 122 ft. to the mile. The main line, reduced to 10 in., passes southward from Whitewood and serves Sturgis, Piedmont, Black Hawk, and Rapid City—the present terminus and headquarters of the Black Hills natural-gas system.

An item of engineering interest is the variation in elevation of the points served along the line, the extreme being that of Rapid City (3,229 ft.) and Lead (5,119 ft.) at the lower end of Main St., with a maximum elevation in that mining camp of 5,380 ft. above sea level.

The gas company operates in the several communities under uniform franchises, which prescribes a sliding scale rate per 1,000 cu.ft. consumed, but simple calculation shows that gas under 5 oz. pressure per square inch passing through the miner's meter at Lead contains exactly 8 per cent less heat units per cubic foot than the same gas in the valley below at Rapid City. The gas company compensates for this variation in density and discounts by 8 per cent the monthly gas consumption (meter reading) of all residents of the mining camps served.

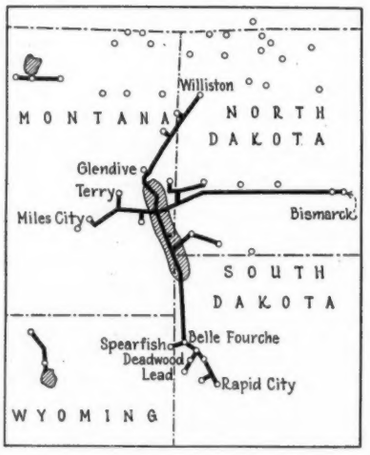


Fig. 1—Sketch map showing distribution system from gas fields in Montana to Homestake mine at Lead, S. D.

A typical analysis of the gas is as follows: methane, 94.0 per cent; nitrogen, 5.81 per cent; carbon dioxide, 0.19 per cent. Methane is the only hydrocarbon present. Neither carbon monoxide nor hydrogen has been detected. This is fortunately a *dry gas*, the absence of moisture greatly facilitating its transmission in the winter season. A calorimeter test corrected for 60 deg. F. and 30 in. of mercury indicates 948 B.t.u. per cubic foot (gross). Under altitude conditions at Lead, and after the 8 per cent compensation discount, the cubic foot of gas as billed has a heat value of 868 B.t.u. Price for industrial purposes is a flat 30c. per 1,000 cu.ft., giving it consequently a cost of 34.5c. per million potential heat units.

The gas is without odor, but, for reasons given later in this article, it is odorized by addition of "calodorant," a special product of the oil refining industry.

The 6-in. transmission line enters the city of Lead from the west, where there is maximum elevation. A station for regulating pressure and for metering flow, on the outskirts of the city, drops the initial pressure of 180 lb. per square inch to from 25 to 30 lb., at which pressure the gas is delivered to the several departments of the Homestake company that are utilizing this efficient and inexpensive fuel.

For domestic requirements of the city, this intermediate pressure line, after further reduction in pressure of the gas to 5 oz., feeds the 6-in. low-pressure system (distribution mains), which for the most part are laid 24 in. underground in the alleys parallel to the main street. The rough topography of the region and the use of high terraces for building sites has led to the development both at Lead and Deadwood of a unique system of entering the basements of houses on one side of the street by service connections from the low-pressure distribution line, while entrances to the houses across the street from the same line are through the roofs.

Another interesting feature is that of ground subsidence at the lower end of the city above the underground workings, in the so-called condemned area, where fissures show in the pavements of streets and alleys, and wide cracks appear in the brickwork and stone walls, giving warning for the occupants to move uptown. What might have resulted in many broken mains and severed house connections has been taken care of from the start by the use—standard for the entire line—of the Dresser sleeve coupling, a type of expansion joint that allows the pipe to conform to the changing earth conditions, enough freedom of movement of the pipe being provided within these sleeves to prevent breakage, which is further minimized by the use of welded joints for long lengths between couplings.

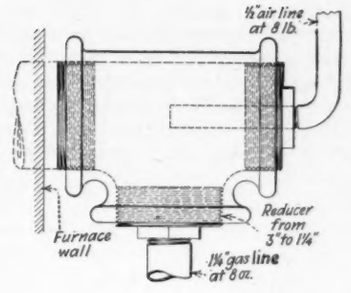
To provide against undetected leakage of gas from broken mains, the gas company, at the pressure reducing sta-

tion outside the city limits, feeds into the intermediate pressure line about 2 gal. of "calodorant" per 1,000,000 cu.ft. of gas, which is sufficient to give it enough odor to warn of line leakage or burners left open by carelessness of the consumer. Continuous service is further provided for by the development of looped mains, so that, if a section is cut off by caving ground from service on one line, the load is automatically taken up by an interconnecting line.

Additional precautions within this condemned area to guard against violent subsidence include the use along the distribution line (low-pressure system) of swinging points and emergency cut-off valves at short intervals.

Natural gas takes its part in gold production at the Homestake mainly by replacing liquid fuels formerly used in the assay office, gold-precipitate refinery, amalgam retorts, drill sharpening and blacksmith shops, and foundry. It is also used at one of the outlying stamp mills, the Pocahontas, for heating the building and for providing hot water in the change room. The company hospital building, formerly equipped with an automatic oil burner for steam heating, has changed to natural-gas burners under the low-pressure boiler, with greatly increased economy and cleanliness. As a substitute for coal for generation of steam at the Homestake's central power plant, natural gas can possibly never compete with the coal received from a subsidiary company, the Wyodak Coal and Manufacturing Company, mining by stripping methods, at Gillette, Wyo., a 70-ft. horizontal seam of clean sub-bituminous coal. This is unquestionably the largest available deposit in the western hemisphere, and low operating costs—the overburden is loose and less than 30 ft. deep—permit the Homestake to have under its control a fuel supply for steam generation delivered at Lead at a cost of less than 13c. per 1,000,000 theoretical heat units. For burning under large boilers with mechanical stokers, as at present, or as pulverized fuel after drying at the mine, this low-cost fuel can have no competitor at existing rates in gas.

In converting the existing furnaces from oil to gas two conditions were observed: (1) Design was left in the hands of each department head, who made burners to fit each type of furnace. In some cases, repeated changes of design were necessary before results were satisfactory. (2) Gas burners were designed to admit an air supply line of the same size as used with oil, and the gas supply line entering the burners corresponded in size with the former oil lines, which were kept in place adjacent to the burners. This permits a return to oil by quick substitution of burners in the event of interruption of gas supply.



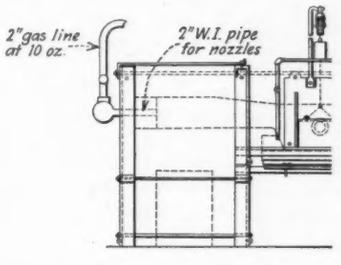


Fig. 2—Burner for muffle assay furnace (above); furnace connections (below)

Assay furnaces at Deadwood and Lead are now operating with natural gas, at a lower fuel cost per furnace day than was possible with other fuels. Assayers report cleaner conditions, and point to white walls and ceilings, whereas oil soon turned them black. The flame appears less jumpy, and stack temperatures are lower.

The single-tier muffle assaying furnaces used, resting on a supporting bench, have a chamber under the muffle too small for ideal combustion conditions unless a thorough mixture of fuel and air is effected outside the chamber. All burners in this department, made from ordinary pipe fittings, operate on the principle of using a high-velocity air jet from a small-diameter nozzle arranged within a malleable-iron tee, to induce lower pressure in the gas stream entering through a reduction opening in this tee.

Fig. 2 shows the assay-furnace burner; Fig. 3 the precipitate-refining furnace, converted to gas firing, adapted from the typical English cupellation furnace. Fig. 4 depicts the burner used under the amalgam-retort furnaces, where control of temperature during the distillation period, easily obtained with gas, is of great importance.

In the laboratory, natural gas has replaced gasolene and Blaugas (formerly shipped in high-pressure containers from St. Paul) for hot plates, Bunsen burners, and blast lamps, without change in the burners other than that involved by the substitution of smaller gas orifices.

Before conversion to gas, distillate, costing at the shop 7½c. per gallon, was used with air in the drill-sharpening shop for combustion at 9 oz. pressure. The type of furnace is shown in Fig. 5, which remained unchanged when converted to natural gas. A 15-day test run, made during March, 1929, (see Table I), indicated a fuel cost with gas of about one-third that of distillate—a result more than realized in practice during the calendar year 1930, which was the first entire year during which gas was used exclusively, in all sharpening and hardening furnaces. In 1928, when distillate was used in all furnaces, a fuel cost was incurred of 8.44 mills per bit shaped and hardened, which was reduced by gas to 2.71 mills for the year 1930. This saving per drill, multiplied by the number of drills treated that year, amounted to $5,832 in favor of natural gas. In part explanation of this drastic cut in fuel costs, the cost of theoretical heat units in distillate compared with gas was in the ratio of 1 to 0.65. Further, the larger number of drills handled per furnace year using gas gave a better thermal efficiency. An additional analysis of results, detailed in Table II, shows that the actual heat unit (B.t.u.) input per drill with oil was more than double that with gas, proving that combustion efficiency and flame control are greatly superior when gas is used.

These excellent results accrue mainly because of the intimate premixture of gas and air in the type of apparatus designed and constructed by the mechanical department for drill sharpening, and illustrated in Fig. 6. This consists of a 2-in. diameter wrought-iron pipe, with air entering at one opening at 6 oz. per square inch pressure, and an air-gas mixture flowing from the opposite end. For 9 in. this air pipe is jacketed by a 3-in. standard, wrought-iron pipe, welded at its ends to the inner pipe, and having, close to the air-flow side, a ¾-in. opening through which gas at 9 oz. pressure enters the annular space between the pipe. Fifteen ⅛-in. diameter holes are drilled 3 in. from the welded junction of the two pipes, evenly

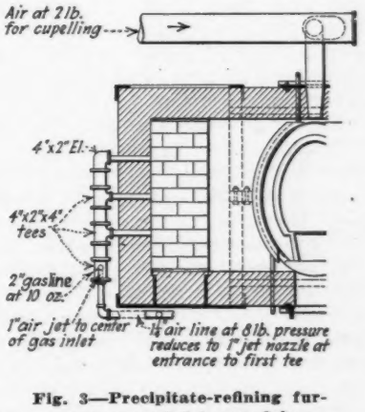

Air at 2 lb. for cupelling
4"x2" El.
4"x2"x4" tees
2" gas line at 10 oz.
1" air jet to center of gas inlet
¼ air line at 8 lb. pressure reduces to 1" jet nozzle at entrance to first tee

Fig. 3—Precipitate-refining furnace, converted to gas-firing

spaced over the circumference of the inner pipe. These slope 45 deg. in the direction of the air blast, and also 45 deg. to tangents at the center of each hole, which arrangement gives maximum turbulence within the air pipe and accounts for the intimate mixture of gas and air ahead of the furnace. Combination of methane and oxygen, is effected with difficulty except in high-speed mechanical mixers; and the success of the low-pressure burners developed at the Homestake is the result of careful design and the exact proportioning of parts.

Table I—15-Day Drill-Sharpening Tests March, 1929

	Distillate	Natural Gas
Cost of fuel per furnace.....	$45.16	$16.29
Difference in favor of natural gas.		28.87

Seven sharpening and hardening furnaces are in operation, of the type shown in Fig. 5, no change other than that of conversion to gas having been made. The design follows standard practice for drill-sharpening furnaces—a brick-lined rectangular trough, of inside dimensions 11 in. wide x 12 in. high x 18 in. long. The brick cover is provided with side passages 3½ in. x 18 in., in each of which rest the points of 12 to 15 drills, facing the gases of combustion and radiant heat from the firebox and cover. When oil was used, a curtain of high pressure air was found necessary along the furnace throats, supplied by means of a 1 in. pipe perforated on its upper surface by ⅛-in. orifices, serving to bend the flame upward and away from the operator. Although retained, they have less significance with gas, because combustion at each furnace was seen to be under perfect control by regulation of the respective air and gas-supply valves. To hold the furnace atmosphere at an approximately neutral condition, so desired in this kind of work, was entirely practicable. Moreover, inasmuch as combustion takes place near the bottom of the brick chamber, escaping tongues of flame are to a large extent avoided. Operators consequently could work nearer the furnace, and the resulting sharp and steady flame allowed them clear vision of the color of the bits—a distinct advantage for careful heat treatment. When using distillate the unavoidable changes in oil pressure caused a wavering flame, particularly when feeding directly from the oil pump. Brick linings now last about two months. Air for the seven furnaces is supplied by a No. 6 E, Buffalo Forge fan, operated by a 10-hp. motor at 3,400 r.p.m. and delivering 1,240 cu.ft. per minute against 9 oz. pressure.

Vanadium and plain carbon drill steel is used, 1-in., quarter-octagon, hollow. For regular work the drills are given a four-point bit; short lengths needed for blockholing, known as jap steel, are given a six-point bit. Four distinct operations are involved:

1. *Sharpening,* done in the five double furnaces (one for japs) at a lemon heat (1,750-1,850 deg. F.), followed by alternate swaging of wings under vertical air-hammer dies, and upsetting in horizontal forming dies.

Cold steel comes to heat in 2 to 2½ minutes, depending on its position on the brick shelf at the throat of the furnace. The skill and speed of the operator is apparent from the fact that he is placing, every other minute, six cold drills on this shelf, holding the points of six heated drills at the right distance from the furnace throat to prevent scaling or overheating, turning all twelve at brief intervals, and operating one or the other pneumatic shaping hammer. East Indian jugglers have something to learn from these operators.

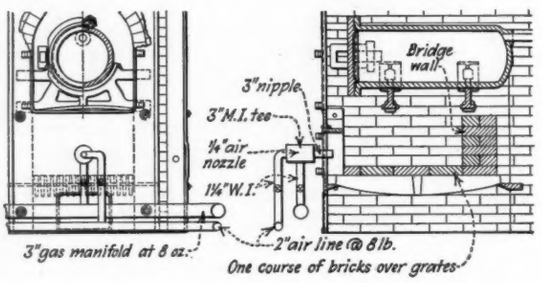


Fig. 4—Gas burner applied to five amalgam-retort furnaces, one of which is shown

2. *Normalizing,* or air cooling, is performed on steel trucks, which are slowly moved to the end or hardening furnace. Grain structure undergoes refinement in this transfer with removal of stresses set up during forging.

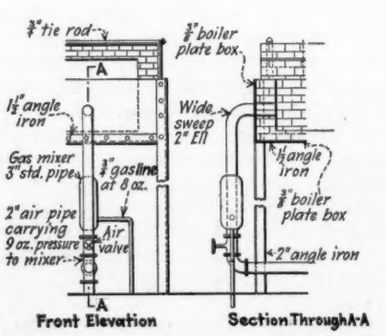


Fig. 5—Homestake drill-steel furnace

Table II—Drill-Sharpening Shop Comparison of Fuel Costs, 1928 and 1930

	1928	1930
Kind of fuel.....	Power disltillate and fuel oil..	Natura gas
Number of double furnaces.....	6.....	7
Heat value of fuel	141,800 B.t.u. per gal.....	868 B.t.u. per cu.ft.
Cost of fuel.....	7.5c. per gal. ..	30c. per M. cu.ft.
Quantity used...	86,707 gal.....	9,191,000 cu.ft.
Cost of fuel per year.....	$6,503.04.....	$2,757.29
Cost of fuel per furnace-year...	$1,083.84.....	$393.89
Number of drills sharpened for the year.....	769,857.....	1,017,838
Cost of fuel per drill sharpened	$0.00844.....	$0.00270
Difference in favor of gas per drill.	.....	$0.0057
Drills sharpened and hardened..	8.88 per gal....	110.7 per M cu.ft.
Cost of fuel per million theoretical heat units..	52.9c.....	34.56c.
B.t.u. input per drill.....	15,970.....	7,838

3. *Hardening*—The No. 5 furnace, at the end of the line, takes the product from four sharpening furnaces. Two operators, working independently of each other on opposite sides of this furnace, place bits on the shelf in the path of the hot gases at the proper distance to bring the steel to 1,600 deg. F., turning the drills through 180 deg. twice during the heating period, which averages 2½ minutes. After withdrawal, the steel is held for a moment in the air until the tip only for a distance of ⅜ in. to ½ in. from the end is a full cherry red (1,460 deg. to 1,410 deg.), at which stage it is quenched in running cool water. No drawing or tempering is practiced, the hardening being confined strictly to the cutting edge of the bit. After trial of many pyrometric devices, the unaided naked eye is back on the job with increased speed and best record for defective points charged against the shop.

4. *Oil Hardening* is applied to shanks, for new steel and culls from sharpened bits. After squaring the ends by grinding, the shank is forged as in Operation 1, then heated as in Operation 3 for a distance of 1½ in., and quenched in a mixture of equal parts of fish oil and Houghton's No. 3, which develops a tough structure that is highly resistant to fracture by the drill hammers.

Table III contains further data covering the kinds of drills sharpened, with cost per drill of the separate operations. The low proportionate cost of fuel compared with the total cost—7.6 per cent—is striking evidence of the economy of natural gas when properly applied for this work.

In the blacksmith shop an interesting type of portable gas blowtorch has been developed, which is giving remarkable results for preheating material previous to welding. This same torch has also been adopted by the foundry for drying molds, freshly lined ladles, cupola spouts, and for lighting the furnace charge.

Mixture of gas and air takes place in a Homestake burner, shown in Fig. 6. These burners are made in different sizes, according to the power of the required torch. The outlet, which may vary from 1 in. to 2½ in. diameter, connects by threaded coupling to a short pipe of any convenient length, tipped with a special whirling nozzle. Details for the 2½ in. size are shown in Fig. 7. This, adapted from the cooling-pond spray nozzle, completes the mixing of gas and air, and holds the flame close to the outlet throughout all variations in pressure. In the smallest-size torch, Fig. 8, natural gas enters the annular chamber by a ½ in. opening under 10 oz. pressure. Air is taken from the 90-lb. service line through a ⅜-in. valve, cracked to reduce pressure to the desired limit. Thus, high-velocity air induces gas through the ring of holes opening into the gas chambers, giving an intense, sharp, purple flame, which can be varied in volume to suit the work by adjustment of the valves.

Several heating furnaces of the box type have been designed, for the most part being similar to the drill sharpening furnace, with variations in inside dimensions and number of Homestake burners, used without spray nozzles. One pit furnace, 4x1x1 ft., with a burner at each end, heats ⅜-in. plates before they are bent double to form mine-car hinges. Another is for heating steel shafting, up to 12-in. diameter, before steam-hammer forging. This is done in 25 minutes with gas, whereas formerly, with coal, the job required from 2½ to 3 hours.

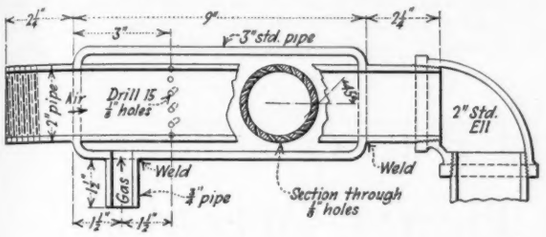
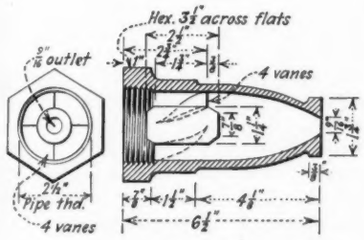


Fig. 6—Homestake gas mixer for drill-steel furnace shown in Fig. 5


Hex. 3½" across flats
2¼"
2½"
1½"
⅜
⅝"
⅜
⅝"
⅜
⅝

The Homestake and Golden Star claims, the foundation of the fortunes of the Homestake Mining Company, were staked in the same year (1876) in which the telephone was invented. Commercial electric-current generation and the evolution of the incandescent lamp followed in 1879, the year in which one of the earliest commercial electric circuits was built—a telegraph line from Cheyenne, Wyo., to Lead and Deadwood, S. D. The Star mill of the Homestake company was the proving ground for one of the earliest types of dynamo—a 75-light (16-cp.) machine. The assay office was the first department to be completely electrified with motors. Copper plates were electrolytically coated with silver at an early date, and the generator still used for this purpose is a museum specimen, although still in service. From such beginnings have been evolved the elaborate plants and complicated transmission networks that link the many mining and production units of the Homestake company.

J. F. Wiggert
Electrical Engineer

Plant and Practice in Electric Operation

The present status of the uses of electricity by the Homestake company for power, lighting, and other purposes is the result of an evolutionary process that has been going on for many years. The company was a well-established concern long before electricity was applied to industrial operations. As soon as the successful use of electricity as motive power was demonstrated, the company began to substitute electric motors for steam engines. All such engines have been replaced in milling and mining operations, except a few steam hoists, which will probably be replaced by electric hoists within the next few years.

The stamp mills were the first units to be motor driven. In the older mills are ten stamps in each unit. In the new South mill, the stamps are heavier, with only five head per unit, each unit being driven by a 25-hp., 440-volt, 600-r.p.m squirrel-cage induction motor, with gear-driven countershaft attached. On the countershafts are pulleys for driving the camshafts at 45 r.p.m.

The rod mills and tube mills are each gear-driven by a wound-rotor induction motor. The large machines have 100-hp., 2,200-volt motors; the smaller ones, 35-hp. motors. Classifiers, which operate in connection with the grinding mills, are separately driven by small 440-volt squirrel-cage motors.

In the sand and slime plants are motors to drive air compressors, various kinds of pumps, sluicing machines, thickeners, zinc feeders, and other equipment. They range in size from a fraction of one horsepower to 200 hp. They are all 440-volt, squirrel-cage motors except one synchronous machine that drives an air compressor.

Mine pumping is done with three-stage centrifugal pumps, each direct-driven by a 2,200-volt induction motor. The pumps, in duplicate, are in chambers 300 ft. apart vertically. All of them, except those on the lowest levels, have a capacity of 1,000 gal. per minute, against a head of 325 ft. Those on the lower levels have a capacity of 500 gal. per minute. Large pumps are driven by 125-hp., 1,740-r.p.m., motors; small ones, by 75-hp. motors. All pump motors except those installed during the last few years are the wound-rotor type. The later motors, of the squirrel-cage type, are as satisfactory for this kind of pumping as the more expensive motors. Pump motors are all automatically controlled by mechanisms operated by floats in the pump sumps.

The pumping plant for supplying water for Lead, and the major part for milling purposes, is also equipped with motor-driven pumps. In this plant are five centrifugals, for pumping against a 400-ft. head. Each is direct-connected to a 2,200-volt, wound-rotor motor, with manually operated controller. Three 2-000-gal. pumps are each provided with a 300-hp. motor; one 1,000-gal. pump has a 150-hp. motor; and one 500-gal. pump, one of 75 hp.

The largest electric hoist in use is at the Ellison Shaft. It is of the direct-current type, with Ilgner-Ward Leonard control. The winding end consists of a 1,400-hp. motor, direct-connected to the hoist shaft, upon which are mounted two cylindrical drums. The maximum rope speed of the hoist is 2,000 ft. per minute, and the hoisting depth is 3,200 ft. It is used for hoisting ore, handling men, and for general work. Ore hoisting is done with self-dumping skips of 7 tons' capacity. When not hoisting ore the skips are replaced by double-decked cages.

The motor-generator set for the hoist consists of a 1,200-hp., 2,200-volt, wound-rotor, induction motor, direct-connected to a 33-ton steel-plate flywheel, an 1,100-k.w., direct-current generator, and an exciter.

Another hoist similar to the one described in the foregoing has been ordered to replace the Ellison steam hoist. It will have a 1,000-hp. direct-current motor geared to the drum shaft, and is designed to operate one double-decked cage and a counterweight in a shaft 4,000 ft. deep, at a maximum rope speed of 1,500 ft. per minute. The motor-generator set will consist of a 1,000-kw. generator, 1,000-hp., 2,200-volt, wound-rotor, induction motor, a 32-ton flywheel, and an exciter.

An induction motor hoist is being installed on the 2,000-ft. level at the Milliken shaft, the double cylindrical drums of which will be gear-driven by a 300-hp., 2,200-volt, wound-rotor motor. This hoist will handle two double-decked cages operated in counterbalance. The maximum rope speed will be 1,200 ft. per minute, and the hoisting depth 1,500 ft., or down to the 3,500-ft. level.

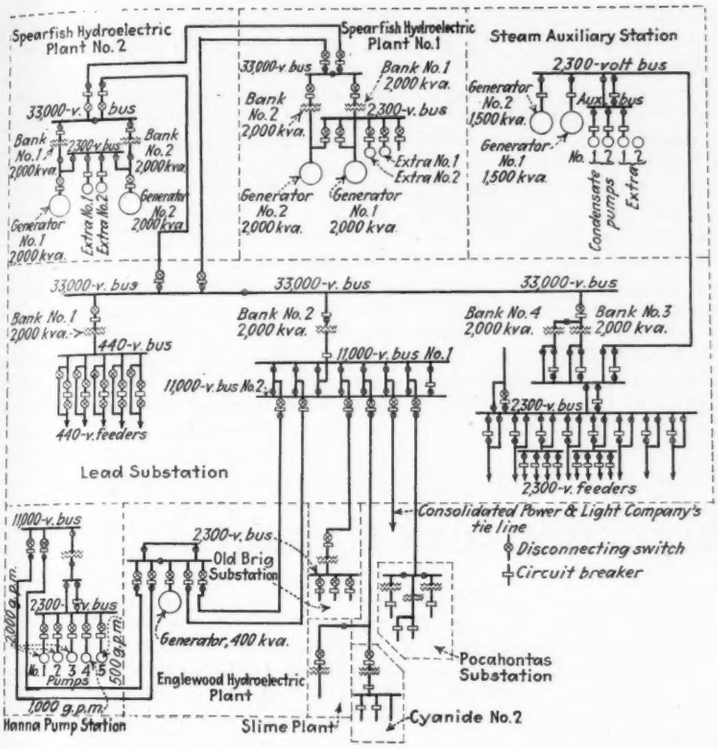
Each crusher is driven by a 2,200-volt induction motor, ranging in size from 35 to 250 hp. No. 6 and No. 8K gyratory crushers are belt-driven by 35- and 75-hp. wound-rotor motors, respectively. Wound-rotor motors of 125 hp., belt-driven, are used to operate the jaw crushers. The 7-ft. coarse Symons crushers are direct-driven by 250-hp., squirrel-cage motors.

The are compressors are driven by 2,200-volt synchronous motors. Four compressors are provided to supply 100-lb. or low-pressure air for rock drilling and other purposes; three for 900-lb. or high-pressure air for locomotive haulage. The motors, ranging in size from 500 to 1,000 hp., are direct-connected except two which have rope drives.

For mine ventilation a large fan is provided on the surface, belt-driven by a 300-hp., 2,200-volt, wound-rotor motor. The fan has a capacity of 225,000 cu.ft. of air per minute against 4¼-in. water-gage pressure. Originally this motor had a squirrel-cage rotor, but the severe starting duty was too destructive of that type of winding. Another mine ventilating unit is being installed. It is a duplicate of the one described in the foregoing.

Underground are several small motor-driven fans for supplemental ventilation, semi-portable and often moved. Most of them are driven by direct-connected, 220-volt motors.

In the various shops the machines are driven by motors. Some are group-driven, but many have individual motor drives. Several electric elevators are in service, automatic and hand controlled, in the various buildings. Electric travel-



Wiring diagram, Homestake operations

ever practical, large lighting units are used.

Wiring and electrical construction in the plants on the surface is according to the rules of the National Board of Fire Underwriters. Underground work is also in accordance with those rules, of course, but in addition it is done to stand the severe service conditions that are incidental to local mining operations.

The following description of the wiring and cable system in and around the Ellison shaft will give an idea of underground electrical construction: Conductors of the main power cable, having a cross-section of 350,000 circ.mil, are rubber insulated, taped, assembled with jute filler in a spiral lay, and covered with jute-covered galvanized steel-wire armor. The primary lighting cable is of the same construction, but the conductors are No. 2 B. & S. gage. Both cables are insulated for 5,000 volts, but are used for a 2,300-volt service to three distribution stations underground. The cables are suported with cast-iron clamps at 12-ft. centers, and attached to the shaft timbers with lagscrews. Continuous cable lengths are arranged between stations, to avoid joints in the shaft. To lower these cables into the shaft, was somewhat of a task, the heaviest section weighing 12,100 lb. Care had to be exercised not to subject the insulation to excessive crushing pressure while passing it over diverting sheaves. In clamping the cables to the timbers, the uneven stretch, caused by tension, had to be considered and also a small amount of slack left to compensate for contraction during probable subsequent lower temperatures.

In each substation is a bus for 2,300-volt power service. The main cables are connected to their respective buses through disconnecting switches. All tap connections to the buses are made

ing cranes have also been installed to facilitate operations.

Among the electric machines used extensively by the company are arc welders, rivet heaters, and a spot welder. Almost all rivet heating is done with electric machines. Spot welding has replaced riveting on many of the small-rivet jobs, such as making tubes or pipes of galvanized or black sheet steel.

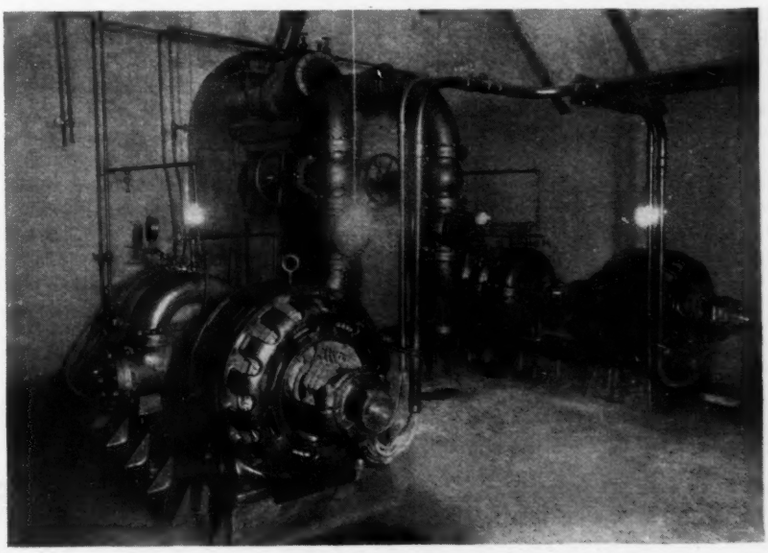
A telephone exchange with a 200-drop switchboard is operated by the company. All of the plants, offices, and mines are well equipped with telephones. In some of the larger plants are also inter-plant telephone systems, in addition to the exchange connections. Independent telephone systems serve to connect the skip-loading stations and the hoisting engineers.

Signaling between cage tenders and hoisting engineers is with electrical signaling apparatus. In the latest installations a separate wire from each station switch in the shaft connects to an annunciator on the engineer's platform. With this arrangement, the engineer always has a positive indication as to where a signal originates. The annunciators are equipped with self-restoring drop attachments, connected to the hoist-control levers.

The latest cage-calling system uses electric horns, with pull-switches near the shaft at each level. The horns are placed in the shaft at suitable intervals, so that the cage tender can hear the signals while he is riding the cage.

Electrical signaling systems, extensively used in connection with ore tramming underground and on the surface, consist of colored lamps controlled by special switches, placed so that the men can operate them from the moving trains.

Electric lighting is according to illuminating engineering principles. Efficient lamps in suitable reflectors are spaced to give uniform and sufficient light on the floor or working level. The intensity of the illumination in any building, of course, is governed by the nature of the work carried on. Wher-



Electrically operated pumps on 800 level

through disconnecting switches and expulsion fuses. Distribution feeders consist of rubber-covered wires run in steel conduits, held in place in the shaft by cast-iron clamps. Cast-iron junction boxes are connected into the conduits at intermediate levels for connecting conduits and feeders for those levels. The vertical wires are supported by wooden clamps bolted to projections in the boxes. For small motors, a 220-volt, three-phase service is supplied from transformers in the substations. In each station is also a transformer for supplying 110-volt service for mine lighting. In these stations are also terminal boards for the telephone cables. Lines for telephones on intermediate levels are run in a system of small conduits in the shaft. Shaft telephone cables, and also those for shaft signals, consist of rubber-covered wires protected by galvanized steel-wire armor. They are supported in the same manner as the power cables.

All high-voltage wires on the various levels are run in steel conduits, and are painted a distinctive color. In addition they are marked with signs calling attention to the fact that they contain high-voltage wires.

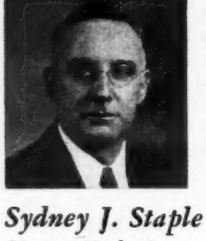
The company owns and operates its own power stations where three-phase current is generated at 60 cycles. The accompanying connection diagram gives the capacities of the various generators and also the transmission voltages.

About 365 motors are in operation at the various mines and plants of the company. These are of all sizes, from a fraction of one horsepower to 1,400 hp. Many of these motors, such as those that drive the stamps, operate continuously for many months at a time without a stop.

During the first six months of 1931 the total current generated was 23,243,200 kw.-hr. Of this, 82.5 per cent was generated by water power and 17.5 per cent by steam. The average daily output was 128,415 kw. or an average per hour of 5,350 kw. The average daily load factor was 82 per cent, indicating economical utilization of electricity from the power generation point of view.

Equipment Inspection and Repair

When industry in general realizes the efficiencies resulting from continuous operation—24 hours per day, 7 days per week—it will understand why the precious and base metals are being produced at so low a cost. This continuity of operations, invariably unavoidable, involves a degree of perfection in mechanical control and maintenance that has been largely responsible for directing attention to the work of the master mechanic, now recognized as one of the most important of operating officials . . . To be privileged to see the Homestake shop organization at work; to be permitted to examine the thousand and one details that have helped to secure the high efficiency observable in every department—this constitutes a liberal education for a mining engineer or a metallurgist . . . The attainment of one's majority in service with the Homestake company is an honor shared by many active members of this great organization. Mr. Staple is a veteran of 35 years' standing, with a wealth of successful experience in the handling of men as well as machines.



Sydney J. Staple
Master Mechanic

Machinery has been one of the indispensable factors in the development of the Homestake property. The first power unit was a Fraser & Chalmers slide-valve, single-cylinder steam engine, the original cylinder of which was replaced with a larger one, when the first mill was enlarged, of Corliss design. A cross-compound, condensing Corliss steam engine, now in reserve at the Nemo sawmill, was purchased in 1896.

The power units have kept pace with the sinking of shafts and the advancement of underground operations. At the B. & M. Shaft No. 1 a Fraser & Chalmers flat-rope hoist is still in continuous service. It was shipped in by ox team and installed in 1879. In 1915 a skip hoist was added—a Nordberg, steam-driven compound condensing inclined unit used exclusively for ore. The B. & M. No. 2 is a standby plant with a Fraser & Chalmers hoist originally installed at the Golden Prospect. At present it is used for lowering timber on the day shift only. At the Ellison, a three-compartment shaft, is a double-cylinder, direct-acting steam hoist built by Union Iron Works, and first operated in 1902. Until August, 1922, two double-deck cages were used. at which time one cage was removed, substituted by a counterweight, to give space in the shaft compartment for one skip of an electric hoist subsequently installed. This steam hoist will shortly be superseded by an Allis-Chalmers electric hoist now in construction. The winding equipment of the Ellison electric hoist was furnished by Allis-Chalmers, and the electrical gear by General Electric. The Milliken shaft, on the 2,000-ft. level, auxiliary to the Ellison shaft, will be used for development. At this point is being erected a Nordberg double-drum, geared hoist with a rope capacity of 1,500 ft.

Ropes are made and repaired in two shops, one at the B. & M. shaft and the other at the Ellison. All flat ropes are made with strands purchased from John A. Roebling's Sons' Company. Flat ropes for the B. & M. skip hoist and the Ellison steam hoist are of seventeen ½-in. strands; for the B. & M. No. 1 and No. 2 Fraser & Chalmers hoists, eleven ½-in. strands. On the Ellison electric, 1½-in. round ropes are used. The electric hoist recently purchased for the Ellison will use 1¾-in. diameter round rope.

A network of air lines circulates throughout the property, one at about 1,000-lb. pressure mainly for ore haulage, the other at 100 lb., for mining operations and general use. Compressors in service include one 2,000-cu.ft. four-stage Ingersoll-Sergeant; two 1,300-cu.ft. four-stage Ingersoll-Rand; three 4,500-cu.ft. two-stage Ingersoll-Rand; one 3,200-cu.ft. two-stage Nordberg; one 1,200-cu.ft. single-stage Laidlaw-Dunn-Gordon; one 1,500-cu.ft. duplex, single-stage Ingersoll-Sergeant; one 650-cu.ft. single-stage Ingersoll-Sergeant; one 830-cu.ft. Imperial-type Ingersoll-Rand; one 370-cu.ft. single-stage, Ingersoll-Rand; and, at the Wyodak coal mine in Wyoming, one 180-cu.ft., single-stage Ingersoll-Rand.

The primary crushing at the B. & M. Shaft No. 1 is done in two Allis-Chalmers No. 8 and four No. 6 Gates crushers. At the Ellison shaft the primary crushing is by 36x48-in. Traylor jaw crushers, one on each of the 800-, 1,250-, and 2,000-ft. levels. On the surface are two Symons 7-ft. cone crushers. Primary crushing at the B. & M. No. 2 is also done on the surface, with two No. 8 Gates crushers discharging over two Hum-mer screens to four No. 6 Gates crushers.

The first pumping at the Homestake was done with a bucket pump driven by a rod and cable from a crankpin on the gear of a small steam hoist at the Golden Star shaft. In 1878 a unit con-

sisting of a small reciprocating pump driven with steam was placed on the 300-ft. level of the B. & M. shaft. A 14-in. smokestack from the boilers was brought to the surface and extended up above the headframe. This arrangement was soon replaced by a Cornish pump.

In 1901 a steam-driven pump of Reidler design, made by Fraser & Chalmers, was erected on the 1,100-ft. level of the Golden Star shaft and gave satisfactory service until replaced by electric-driven turbine pumps, the first of which was started on Jan. 21, 1913. Additional pumps were added as rapidly as possible at intervals of 300 ft. On the upper levels, two 1,000-gal. Jeanesville centrifugal pumps operate at each station, one of which is a standby. On the lower levels are Allis-Chalmers centrifugals of 500 g.p.m. capacity.

Water for domestic purposes and general use is furnished by five electric-drive Jeanesville centrifugal pumps at the Hanna station, 11 miles southeast of Lead. In addition, a great variety of pumps, stationary and portable, are used for treatment and fire purposes.

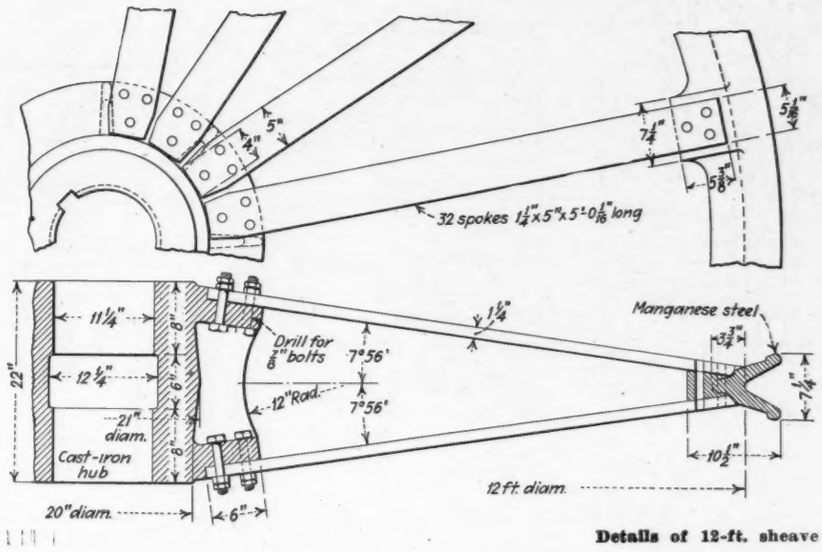
Haulage was first done on the surface by three 5-ton steam locomotives, and by horses and mules underground. Compressed-air locomotives, first used as an experiment in 1901, were successful, and were added to until there are now 35 units, ranging in weight from 3½ to 14 tons. Four of the large ones are used for haulage to the stamp mills, the smaller ones being operated underground. Four-ton cars, bottom dump, are used on the surface tramway, and one-ton cars, side and end dump, in the mine. All cars are equipped with Hyatt roller bearings, in boxes of Homestake design.

Machine shops are grouped east of the Ellison hoist. Railway tracks run through the yards, making direct delivery of material. The buildings are well lighted and ventilated. Change rooms, with shower baths and individual steel lockers for the convenience of the employees, are also provided. The machine shop is 60x140 ft., served by an electric traveling crane in the main bay over its entire length, and equipped with the usual machine tools. Centrally located is the tool room, provided with lathes, shapers and a special machine, electrically driven, for grinding.

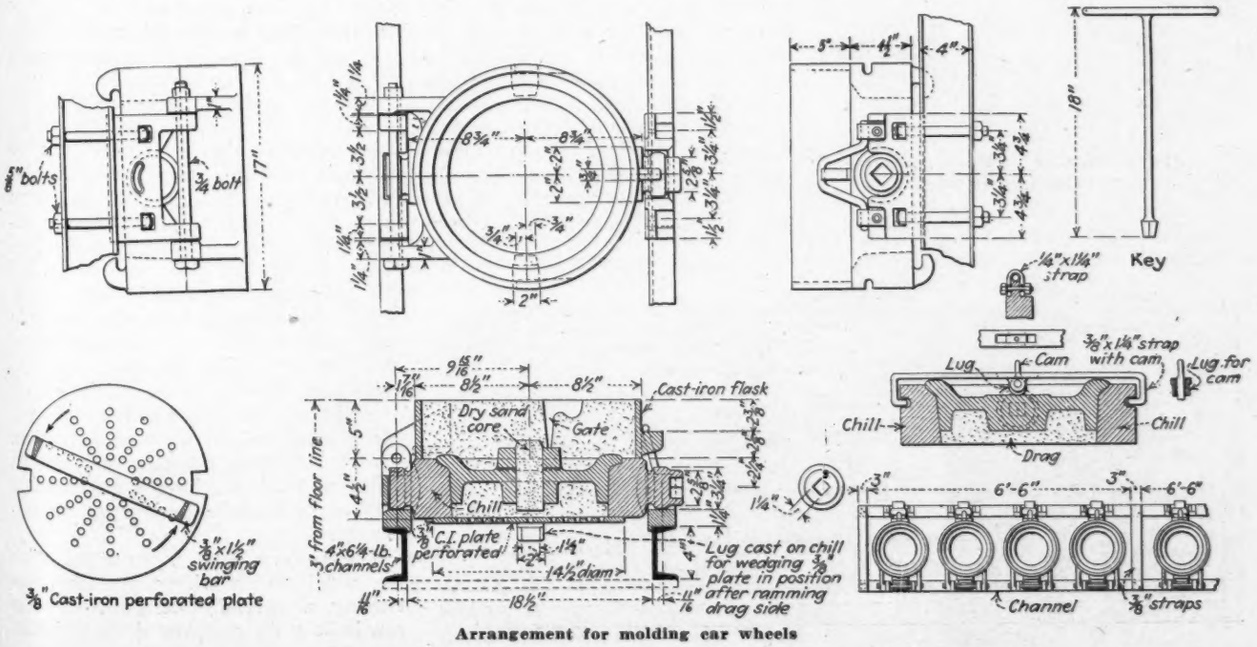
As an adjunct of the machine shop is an automobile repair department, fully equipped to maintain and repair the fleet of 85 trucks, tractors, and cars used for company transportation service. A complete vulcanizing plant permits repairs of tires of all sizes. A 200-ton hydraulic press is used in solid-tire work on trucks.

The blacksmith, boiler, sheet-metal, and tinsmith shops are housed in a building 60x170 ft., where 37 men are employed. The equipment consists of seven forges, in addition to two gas-fired furnaces for special work; two forging machines, three power hammers, threading machine, power punches, shears and power rolls of various capacities, electric rivet heaters, and an electric spot welding machine recently developed to facilitate the making of many thousand feet of galvanized-iron air conduits required for mine ventilation.

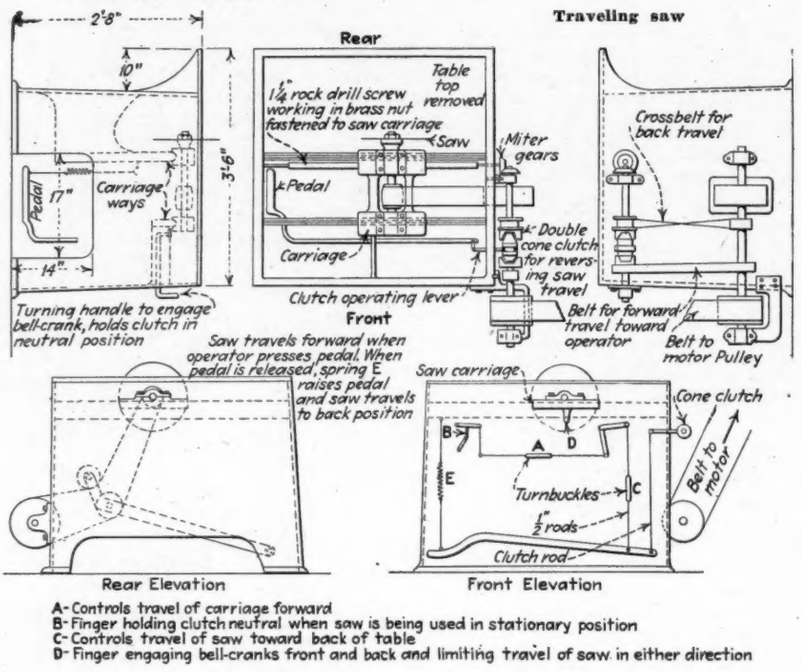
At the drill-sharpening shop 25 men are employed. About 3,000 hollow-steel drills are sharpened daily, six machines for the large drills and five for the smaller ones. These machines are



Details of 12-ft. sheave



Arrangement for molding car wheels

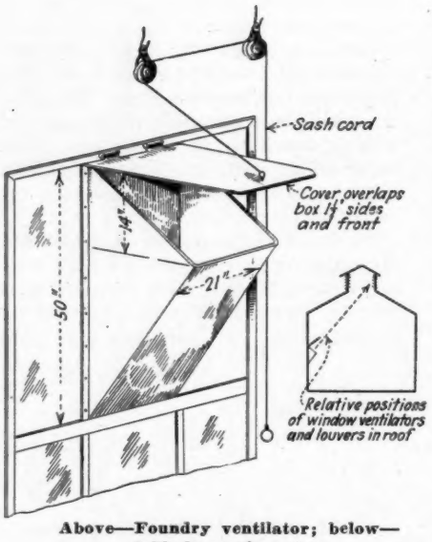


A-Controls travel of carriage forward
B-Finger holding clutch neutral when saw is being used in stationary position
C-Controls travel of saw toward back of table
D-Finger engaging bell-cranks front and back and limiting travel of saw in either direction

ing it at the desired height. See illustration shown on the opposite page.

A special shop takes care of 1,600 end-dump and 1,200 side-dump cars used in the mine. In addition, larger tramway cars are used on the surface, and timber and special trucks of various kinds, all equipped with Hyatt roller bearings in boxes of Homestake design.

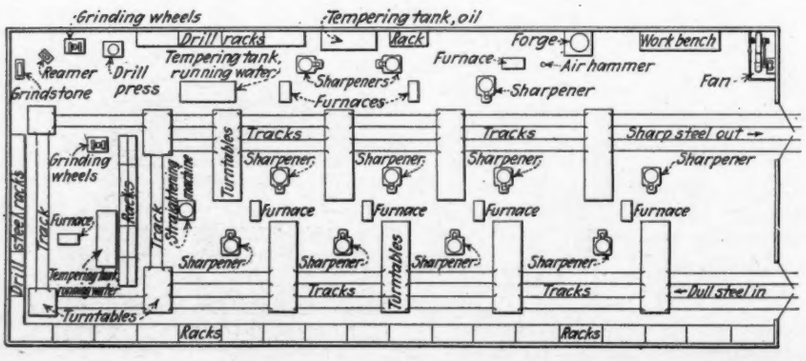
The foundry is 168x72 ft., served by a 10-ton electric traveling crane. Two cupolas are lined to 40 in.; a small one, lined to 22 in., is used for testing and when a small casting is required on short notice. Cupolas are equipped with blast meters. Records are kept of all heats. Two tilting crucible furnaces, fired with natural gas, are used in the production of non-ferrous castings. Chilled mine-car wheels, made on a specially designed rig built in the shops, comprise an important part of the output. These wheels are allowed to remain in the mold overnight and get no further heat-treatment. The mix consists of 40 per cent pig (Si, 1.70; S, 0.030; P, 0.145; Mn, 0.84); 40 per cent returned scrap wheels; 20 per cent drill-steel scrap. This gives a wheel with about ¼-in. chill on the tread.

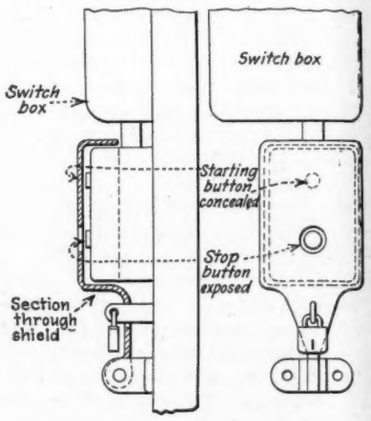


Above—Foundry ventilator; below—drill-sharpening shop

equipped with an air-operated hammer, the larger machines having also a shearing device attached. Natural-gas furnaces are used exclusively. In the tempering operation, drills are heated to about 1,450 deg. F., and quenched in water. Houghton's No. 2 quenching oil is used for the shanks, which are treated at the same temperature. In order to place responsibility for drills that fail in service, defects developing within 3 in. of either bit end or shank end are charged against the sharpening shop.

A noticeable improvement on the large-size sharpening machines was recently developed. By this arrangement the hammer cylinder may be raised or lowered to compensate for the varying height of the dies, the result of redressing. Formerly, piston rods were of various lengths, according to the height of the dies. This meant a serious delay in making the change. The new arrangement permits adjusting the cylinder and lock-





Safety device on motor starter

Ball- and rod-mill liners, weighing 75 to 400 lb., are sand-cast, no chill being used. Cupola charges consist of: 40 per cent returned scrap liners; 30 per cent medium-soft scrap; 30 per cent scrap steel. Approximate casting analysis is Si, 0.070; S, 0.15; P, 0.40; Mn, 0.40. Stamp-mill dies, weighing 110 and 168 lb., are required in large quantities. These were formerly made in sand molds in which was placed a heavy iron disk for chilling purposes. Several years ago, however, a special iron chill or mold was devised, which avoids the use of sand and the molding operation. Two gas-fired core ovens, one 4x8 ft. and one 9x14 ft., have roller-bearing cars of Homestake design and manufacture.

The pattern shop is equipped with the usual woodworking machines including a specially designed circular saw built in the company shops to facili-

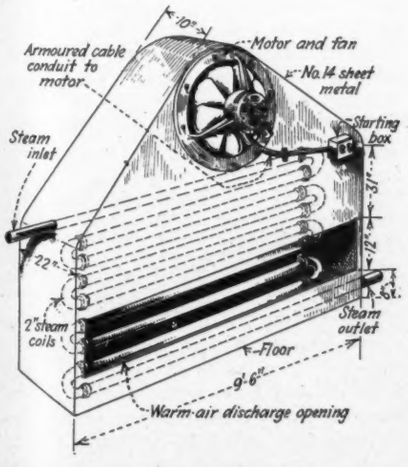
tate the making of wood flasks for the foundry. Patterns are stored in racks alphabetically arranged. All patterns are marked and noted in a card-index system.

The offices of the mechanical department constitute a bureau of information for department affairs. In a card-index file are listed orders for material, date of ordering, and when received—information that assists the foremen, when placing orders for new material, to gage requirements correctly, both as to cost and probable time when the material may be received. Filed here are also copies of specifications covering new equipment, erection date, subsequent performance, repairs, when and where made, name and number of machine or part on which the work was done, and the cost.

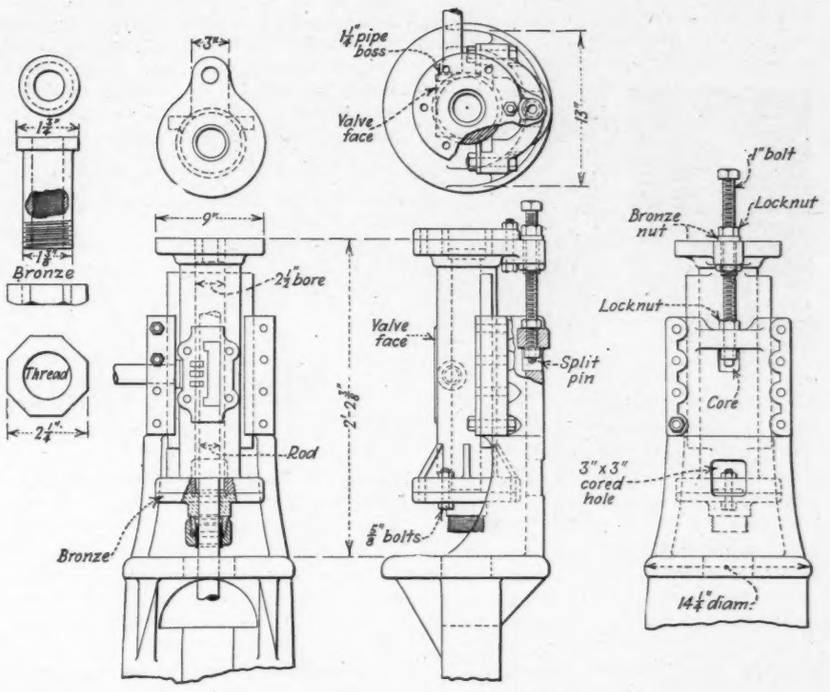
All operators, whether in the immediate vicinity or at an outlying plant, are in touch with this office by telephone. Trouble calls received are at once relayed to the department concerned. Operators are given instructions from this point regarding any desired change in the routine of their work. Once each month, or oftener as occasion may arise, the foremen of the shops meet with the master mechanic to discuss work in progress and to plan the procedure for new work contemplated. Payrolls and shop and material costs for the preceding month are presented by the chief clerk for examination, and a round-table discussion is held, at which suggestions for improvement are invited and considered.

These meetings serve to keep the foremen of the shops in touch with work in prospect, what is likely to be required of particular departments, and enables them to plan accordingly.

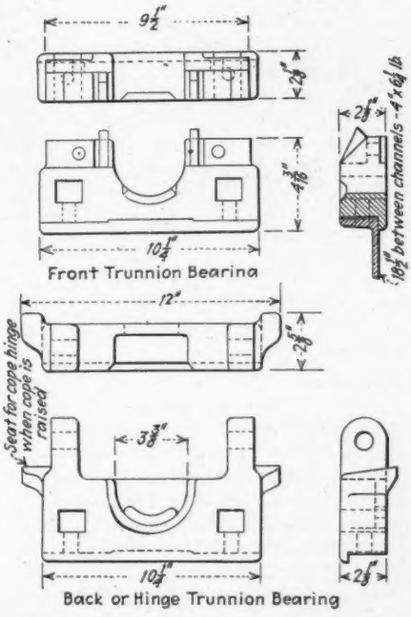
The extent and variety of the work undertaken by the mechanical department of the Homestake company may be gaged by the following references to a few of the major items of equipment maintenance during 1930:



Shop heater



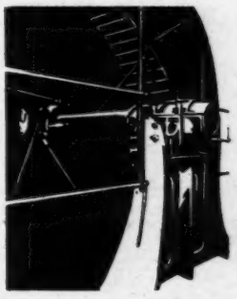
Above—Hammer cylinder device; below—details of trunnion bearing



1. The number of rock drills serviced in the shop per day during a working year of 335 days averaged fifteen, or a total of 5,030 for the year, at a total labor and renewal-parts cost of $7,864. Including 48 new machines issued, the number of these operating units on hand at the end of the year was 490. Drills sharpened and made during 1930 totaled 1,017,838, at a total labor and materials cost of $37,967, not including cost of new steel, which amounted to $31,807. During the working year of 335 days the department repaired an average of eight mine cars per day, or a total of 2,693 cars for the entire period.

2. The foundry, in 1930, consumed 2,347,300 lb. of pig iron, scrap iron, and scrap steel, with a ratio of 1 lb. of coke to 9.59 lb. of metal. Delivery was made of 2,231,104 lb. of iron castings and 24,777 lb. of bronze, copper, and aluminum castings. As a binder for the sand, 5,300 lb. of bentonite was consumed. Labor per pound of casting averaged 2.416c. Iron castings made numbered 26,488 pieces, with 3,443 pieces of brass and other alloys.

3. With a personnel of 260, the mechanical department had a labor turnover of 10 per cent, half of which resulted from the normal return of students to school. Of the remainder, only one employee was discharged. No fatal accident occurred during the period. A total of fifteen major and minor accidents represented an accident rate per 10,000 shifts of 1.92. The high position of the department in the company records is well illustrated by the fact that eight employees have been in service for 45 years or more; nine for 35 years or more; 47 for 25 years or more; and 78 for fifteen years or more.



Surveying

The diamond drill is a valuable working tool for the surveyor and the mining engineer in the operation of mines as well as in the exploratory stages of mining operations. Homestake finds continuous work for two diamond-drill rigs, for prospecting and surveying in uncharted areas. The results of such drilling prove helpful in governing the extent and location of drifting and crosscutting operations. . . . The valuable data provided by diamond-drilling are usually discounted, to some extent, at least, by the uncertainty prevailing as to the direction of the borehole at any one place—because of the difficulty in determining the degree to which the drill has deviated in entering a change of formation or of rock characteristics. Homestake engineers pooled their experience and knowledge, and Homestake mechanics applied a fine craftsmanship, in the invention and construction of a remarkably efficient yet compact instrument, described and illustrated herewith, which provides positive and accurate indications as to the direction of the borehole at any point. Measurements are regularly taken in the Homestake mine by means of this instrument at 100-ft. intervals in all long diamond-drill holes, thereby greatly facilitating forecasting and surveying work and systematizing mine operations.

J. F. Peters
Mine Engineer

Mine Mapping and Sampling

The meridian at the Homestake was determined several years ago by observations on Polaris, and a primary triangulation system was formed. Around the primary triangulation stations a north-south and east-west co-ordinate system was set up. Points were carried from the triangulation stations to the hoist landing; and, by setting the transit in the plane of two wires suspended in the shaft, the meridian and coordinates were carried to permanent underground stations on each level. So all points on the surface and underground are located to conform to this coordinate system.

Survey stations underground are wooden plugs driven in drill holes, in which are set triangular notched spads. These are not marked or numbered, the notes and sketch being sufficient to identify them. Stations on a level are checked through incline openings or by the two-wire method before they are transferred to a level below.

The mine superintendent lays out all mine work. Drifts, crosscuts, raises, and shrinkage stopes are run by lines. Plugs in drifts and crosscuts are moved ahead every 150 ft. In shrinkage stopes and raises they are moved whenever necessary.

Plugs in shrinkage stopes, moved back and forth as the stope advances, are carried two or three feet in the stope from stope line. This distance is reported to the assistant foreman whenever plugs are moved. Elevations are carried on plugs, and the stope is tied in every 25 ft. in elevation.

Incline raises from 20 to 70 deg. are run with stirrup sights. Plugs are set on line after the raise advances 20 to 25 ft., and elevations taken on the spads. The lengths of wires are figured for the degree of raise. So by hanging the wires in the spads the vertical wires give direction, whereas the horizontal wires at the bottom of the triangles give the pitch of the raise. The stirrups are made of No. 20 hard steel wire.

Irregular openings are taken by radiation side shots. Crowns and pillars left after the shrinkage stopes have been completed must be removed by the square-set method, so timber stopes are tied in on the sill or crown, and a reference post is marked. The stopes are surveyed monthly, or whenever finished, by counting square-sets from the reference post.

Notes are kept on 4½x6-in. cards, ruled 8 to 1 in. in light blue. Upon these a sketch of the work done is made, and the deflection angles and length of courses are recorded. These cards are indexed and are kept in files in the office except when actually in use.

All survey stations are computed for latitude and departure, and recorded in regular computation books. Maps are plotted on a scale of 50 ft. to 1 in. and 100 ft. to 1 in. Crane's parchment, No. 44 paper, 19x30 in., is used for regular work sheets, and each sheet shows a certain block of a level. These maps are on a scale 50 ft. to 1 in. Traverse points are plotted by coordinates from the near sides of the square in which they lie. Side shots are plotted with a protractor. Sill-floor workings are shown in black dash lines; sublevels above in colors, according to elevation. New work is tied in monthly, and the maps are brought up to date. Composite maps are made on a scale 100 ft. to 1 in. Series of three levels are shown on these sheets in different colors. Tracings of the different levels are made, and yearly progress is recorded on them with different hatchings and colors for each year. Prior to 1913, no record of samples or assays was made on maps. The records were kept by the sampler in his record book by the name of stope or drift. At that time standard methods of sampling were adopted, and since then all drifts, crosscuts, stopes, and pillars have been sampled in a systematic manner.

The sampling is conducted under the direct supervision of the operating department. Channel samples, 10 ft. long, 4½ in. wide and ½ in. deep, have been taken in all ledge matter throughout the mine. These sample lines are at 20-ft. intervals, because the mining methods demand that a crosscut be run through the center of 42-ft. pillars, and that sill-floor stopes 60 ft. wide be cut before mining of the stopes begins.

Crosscuts, being at right angles to the strike of the vein, are channeled along the side at breast height; stopes and crowns, along each side; and cuts, across the back at 20-ft. intervals. Ledge matter in drifts is sampled at 20-ft. intervals at right angles to the strike.

The ore is hard and tough, and channel samples are taken with moil and hammer. The fragments are caught on canvas sheets spread on the floor of stope or drift. After the cut is made, the fragments of rock are rolled back and forth in the canvas until the ore is thoroughly mixed, after which it is quartered.

The samples are tied in by surveyors, and the assay value in dollars per ton is printed on the map opposite the location. A set of these maps is kept by the mine superintendent and another at the engineering office.

Grab samples, taken daily from cars in the drawhole areas, serve to determine whether the content is ore or waste. Shift bosses take grab and pick samples in all new development raises, drifts, and crosscuts.

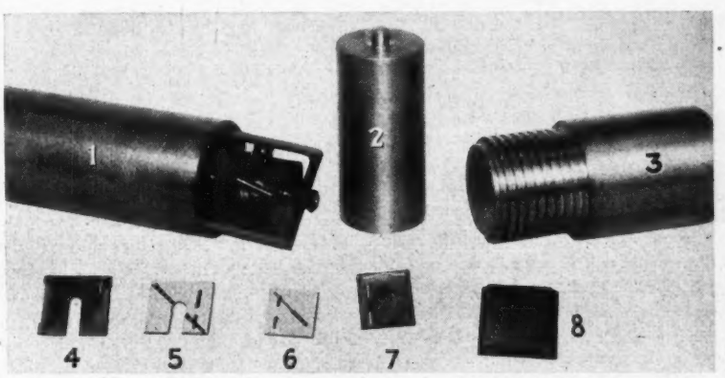
Two diamond-drill rigs are constantly at work exploring new territory and obtaining information that helps to avoid unprofitable drifting and crosscutting. Surveys are made every 100 ft. on all long holes with the Homestake borehole survey instrument, to be described, with satisfactory results. Mr. A. B. Yates discusses the problems in-

volved, and describes the instrument, in the section of this article that follows.

In most instances, he maintains, diamond-drill holes do not continue in the direction in which they are started. If bedding or schistosity is characteristic of the rocks, the bit will almost invariably work its way into a position almost perpendicular to this layering in the rocks, and the hole will deviate from a straight line. Only in homogeneous material may holes be expected to stay "on line."

As it is as important to know where the core came from as it is to know the assay value of the core, and as there is no entirely satisfactory method available to determine the deviation of drill holes, an instrument was developed by Lawrence B. Wright and A. B. Yates, former members of the geological department, and A. A. Lease and J. F. Peters, of the engineering departments of the Homestake company.

The instrument is capable of recording the dip of the hole, as measured from the horizontal, and the magnetic bearings of the hole at any point, by means of a photographic record of the position of a compass needle and the position of a reference line, so arranged that the latter is always perpendicular to the line of direction of the hole. With it the record is obtained on ordinary commercial photographic film, and the light is supplied directly from the needle and the reference line from radium paint.



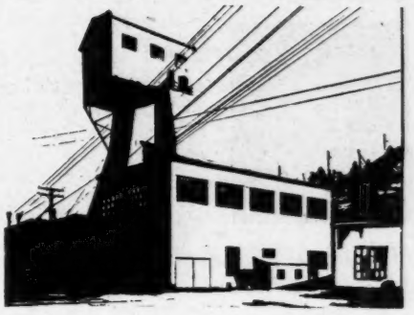
Homestake borehole survey instrument

(1) Brass container with instrument in slots; (2) spring top cylinder for holding instrument in place; (3) screw top for brass container; (4) dip film holder; (5) dip film after having been exposed and developed; (6) needle film after having been exposed and developed; (7) needle film holder; (8) top for instrument.

As illustrated above, the compass needle is mounted on a pivot in a compass bowl suspended within a square bronze box by means of horizontal pivot bearings. The box is suspended within an open frame by pivot bearings at right angles to the horizontal pivots. Both the compass bowl and the box are weighted so that they will swing into an upright position. The apparatus is a compass mounted in gimbal bearings, with parts so weighted that, regardless of position of frame, the inside compass bowl will remain in a horizontal position.

The frame is so constructed that it fits into slots in the sides of a brass container in such a way that the pivots supporting the compass box lie in a line coincident with the long axis of the container. This container is made to screw onto the end of the string of rods in place of the core barrel or the bit; so that, when the container is in the hole, the line of the pivots will coincide with the center line of the hole, and the horizontal pivots will always lie in a horizontal plane. Furthermore, a line through the horizontal pivots will always be perpendicular to the line of direction of the hole. The sides of the box will be vertical, regardless of the position of the frame; and the ends of the box will lie in planes normal to the direction of dip of the hole. As the inside compass bowl always remains in a horizontal position, the dip of the hole may be determined by obtaining a record of the inclination of the box with respect to the horizontal plane of the top of the compass bowl. This record is obtained in a simple manner.

Two small film holders are arranged to slip inside the box against the sides. On each of the holders is a broken reference line painted with radium paint. On each side of the compass bowl is a small groove, passing through the pivots and parallel to the top of the bowl. This groove is also filled with radium paint. The light from the reference line and from the groove on the side of the compass bowl gives two line shadows on the dip film. As the reference line is parallel to the plane at the end of the box, and as the ends of the box are always perpendicular to the direction of the hole, and the top of the compass bowl always remains in a horizontal plane, the angle between the two light impressions on the film is the compliment of the angle of dip of the hole. For check purposes, and to keep the instrument in balance, a film is inserted on each side of the box, so that two dip readings are obtained.



The record of the magnetic bearing of the hole is obtained in a similar manner. The instrument is so constructed that the square top of the compass bowl is always oriented with respect to the direction of the hole—the sides of the bowl are always parallel to the line of the pivots, and thus are parallel to the direction of the hole at all times. A film holder is arranged with a reference line parallel to the sides of the box, and hence parallel to the direction of the hole. The holder clamps over the compass needle and supports the film in a horizontal plane a short distance above the face of the needle. This needle is grooved, and the groove is filled with radium paint. The paint on the south end of the needle is interrupted by black lines, so that the light impression of the needle on the film is a long straight shadow for the north end of the needle, and a dot-and-dash shadow for the south end.

The light from the needle and the light from the reference line give two impressions on the strike film. As the reference line is always parallel to the direction of the hole, the angle between the two line shadows is the magnetic bearing of the hole.

Intensity of light can be readily regulated by the strength and quality of the radium paint used, and the speed of the films may be varied by use of the various grades. Punches have been made so that small films may be rapidly cut to fit the film holders. The intensity of light and the speed of the films have been so regulated that the instrument may be loaded and carried for several hours, as long as it is kept in motion, without affecting the films. The instrument is in constant motion while being let down the hole, so that the films are not affected during that time. After the instrument is in position, about 30 minutes is sufficient time to allow the instrument to come to rest and obtain good light impressions on the films, which are subsequently developed in a standard solution by usual methods.

Professor McLaughlin's discussion of Homestake geology serves to round out the treatment of a major topic of this issue, as well as to present the most widely accepted view of today as to the genesis of the ore deposits, a view supported by recent studies of the rocks and mineralogy of the ore-bearing formation. He concurs with majority opinion in ascribing a deep-seated origin to the orebodies and assigning them, not to the Tertiary, but to the pre-Cambrian, in which wide zone of classification they have the fitting company of other celebrated deposits. Narrowing the classification, he finds acceptable the Geological Survey's term Algonkian for the metamorphosed rocks of the northern Black Hills pre-Cambrian, which have been derived from sedimentaries, recrystallized. Under this head falls the Homestake formation, a layer of cummingtonite-bearing schist, to which the commercial ore is almost entirely confined. So distinctive is this formation that it has supplied the key horizon for working out the structure of the district. The discussion embraces the series of rocks in which the Homestake member occurs; the structural details that are intimately associated with the formation and distribution of ore; and the character of mineralization of the deposits. The article constitutes a comprehensive yet concise summary of the origin and characteristics of one of the greatest occurrences of gold ore in the Americas.

Donald H. McLaughlin
Consulting Geologist

Ore Genesis and Structure

What is known as the Black Hills dome, which interrupts the flat strata of the high plains of South Dakota and Wyoming, is a geological feature of major economic importance, for because of its uplift and erosion the pre-Cambrian basement rocks of the region were elevated and uncovered, and the great orebodies contained in them were again brought to light. In the vicinity of the Homestake mine, the ridges and hilltops are still capped by Cambrian sandstone and dolomite and by thick sills of porphyry, but in the adjacent valleys and steep-sided gullies the underlying slates and schists are exposed. In them, outcrops of quartz and rusty gold-bearing rocks were found in 1876, and the existence of mineral deposits of value was soon established.

The orebodies of the Homestake mine are extraordinary, not only for their magnitude and for the wealth they have produced, but also for the consistent relations that prevail between them and certain controlling geologic conditions. Commercial ore is almost entirely confined to one distinctive layer of cummingtonite-bearing schist of unusual character, named the Homestake formation, which can be traced as a well-defined unit for many miles through the highly folded, metamorphosed pre-Cambrian sediments of the northern Black Hills.

The ledges, as the orebodies are designated in the mine, lie along a group of minor folds that together form a large complex anticline. Each separate orebody follows its own specific fold, usually a minor anticline, and all except the Caledonia ledge, which has certain vagaries of its own, dip steeply to the northeast and plunge at about 35 to 40 deg. to the southeast with the prevailing structure.

The ore consists of cummingtonite-chlorite schist of the Homestake formation, with thin local layers of quartz sand and some original iron-magnesium carbonate, which has been mineralized with numerous irregular veins, lenses and saddles of white quartz and with ankerite, chlorite, arsenopyrite, pyrrhotite, pyrite, magnetite, and gold. The richest ore is consistently along the margins of quartz bodies where the rock contains abundant chlorite and coarse grained arsenopyrite, but the quartz itself is usually barren unless it contains inclusions of material from the Homestake formation. Mineralization of commercial grade, however, may extend along the favorable horizon for several hundred feet beyond the limits of conspicuously good ore.

In form, the orebodies are irregular slabs or pods, with longest dimension parallel to the plunging structure. Their outlines conform more or less to the shape of the replaced bed in the particular folded structure that is followed; but conditions within the favorable rock itself, such as zones of minor fracturing related to shear or tension, distribution of permeable varieties of the altered rock, and other details also influence the distribution of mineralization.

The orebodies and related structures appear similar in form in both horizontal and transverse vertical section, because of the prevailing plunge. Toward the southeast on level maps, or upward on sections, the orebodies terminate against an arch of slate of the stratigraphically overlying Ellison formation, or against parallel structural features. Toward the northwest, or lower stratigraphically, the ore usually terminates against garnet schist or banded phyllite of the De Smet-Poorman formation, though locally the ore may end before the contacts of the formation are reached. Individual ledges range from 50 to 150 ft. thick, and from 300 to 700 ft. along the strike in horizontal plan; but, where several folds and accompanying orebodies are bunched together, widths of over 300 ft. have been mined, and continuous ore followed for more than 1,200 ft. on certain upper levels. Because of the variation in outline, however, as the orebodies follow the changing details of the folds, figures for average dimensions have little exact significance.

The pre-Cambrian rocks and the orebodies in them are interrupted by dikes of rhyolite porphyry, which occur in a ragged zone about 200 ft. broad, which intersects the general schistosity at an acute angle. The general course of the dike zone is a few degrees more to the north in strike and slightly flatter in dip than the prevailing structure of the older rocks. The block of ground on the hanging-wall side of the dike zone (i.e. the northeast side) is elevated about 112 ft. with respect to the footwall block, as well as displaced to make room for the intruded material. The plunge of the orebodies and the convergence in strike of the dikes and folded formations carries certain of the ledges on their downward course into the footwall of the dike zone.

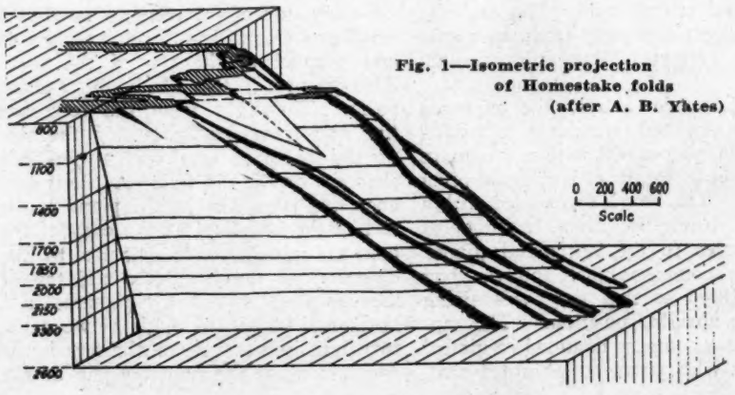


Fig. 1—Isometric projection of Homestake folds (after A. B. Yates)

Correlation of specific structures across the zone can be made with precision, however, and the displaced lower segments of orebodies that apparently terminated against rhyolite are now definitely identified on the hanging-wall side of the dikes.

The Homestake mineralization is believed to be of pre-Cambrian age. . The evidence is positive and compelling that the orebodies were formed at great depth and that they are not related to the siliceous gold ores in the overlying Cambrian beds, which are attributed to the period of Tertiary intrusives. The rhyolite dikes are of importance in mining operations on account of their geometrical relations to the orebodies, but they are in no way genetically responsible for the Homestake gold.

Pre-Cambrian Formations—The slate, quartzite, phyllite, garnet schist and other metamorphic rocks that make up the pre-Cambrian formations of the northern Black Hills are derived from sedimentary material, recrystallized during the long period of intense compression that forced the original beds into tight folds and imposed a well-defined parallel cleavage on most of the rocks. Some sills and crosscutting bodies of diabase in the old sediments were also involved in the changes that affected the region and were altered to an amphibolite, with well-developed parallel texture. The coarse-grained granite and pegmatite, which forms a large batholith in the southern hills, does not outcrop in the northern area. Dikes of pegmatite in Nigger Hill, 15 miles to the southwest, and an inclusion of granite in a porphyry stock five miles to the northeast of the Homestake mine, are its nearest manifestation.

In the vicinity of Lead, a sequence of sedimentary formations has been worked out, and the rocks grouped into five definite formations, which can be accurately delimited and mapped. The stratigraphic column and characteristic rocks are as follows:

Northwestern formation: Green to gray, garnet-mica schists and thick, medium-grained micaceous quartzite.

Upper-ledge formation: Coarse-grained cummingtonite-quartz schist; medium-grained magnesium-iron-carbonate quartz schist; thin white quartz lenses and pods.

Ellison formation: Fine-grained gray slate and slaty mica schist, thin black quartzites, medium-grained gray micaceous quartzites.

Homestake formation: Coarse-grained cummingtonite-quartz schist; medium-grained magnesium-iron-carbonate quartz schist; thin white quartzite lenses and pods.

Poorman-De Smet formation: (Upper tenth)—Coarse-grained garnet-mica schist, fine-grained banded greenish chlorite-garnet-quartz-mica schist; fine-grained banded gray dolomitic phyllite.

Poorman-De Smet formation: (Lower nine-tenths)—Fine-grained banded gray dolomitic phyllite. Banded carbonate-mica schist.

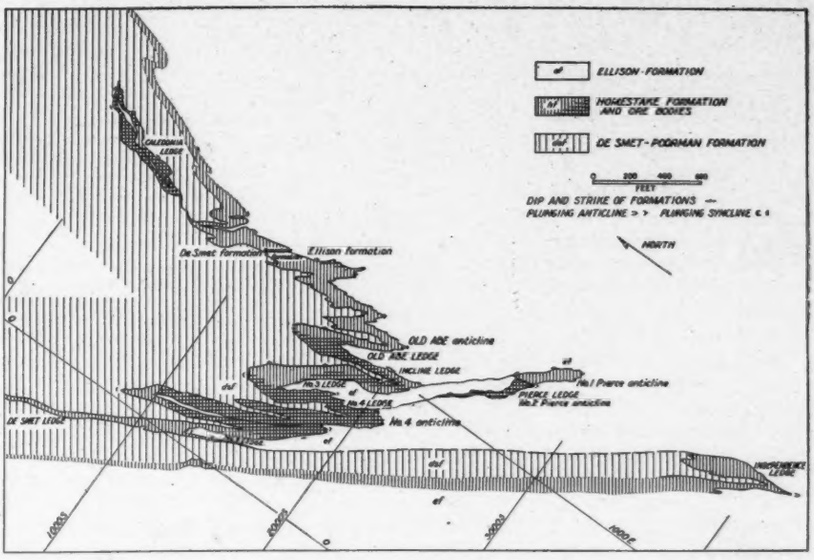


Fig. 2—Structure in horizontal section at elevation of the 800 level, with Tertiary dikes removed and eastern block restored to original position (after A. B. Yates)

Each formation is an assemblage of altered bedded rocks. The types noted, however, are sufficiently dominant to make identification possible in the mine or in areas where outcrops are plentiful. The formations can be traced to the north until they disappear under the Cambrian cover about three miles from Lead. They have been identified at intervals to the south as far as Rochford.

The Homestake formation, to which the orebodies of the mine are almost entirely confined, a remarkably distinctive unit, has furnished the key horizon by which the intricate folded structure of the district was worked out. The sedimentary material from which its present rocks were derived was probably clay, fine quartz sand, and impure iron-magnesium carbonate. The original thickness is difficult to estimate, but 60 ft. can be accepted as a reasonable approximation. Under the conditions of pressure and heat that prevailed during and after the intense folding of the region, these components were recrystallized and in part converted into cummingtonite, an iron-magnesium amphibole. Its characteristic fibrous radiating texture and dull-green or brownish color make it a most useful diagnostic mineral, particularly in mine exposures; but it is less conspicuous on the surface than the brick-red color of the oxidized carbonate. Numerous light-gray sandy layers, contorted into intricate folds and even pulled out and rolled into cigar-shaped pods, are also prominent and significant features of the formation.

Though the formation as a whole is distinctive and its contacts can almost always be mapped with confidence, considerable variation exists within it, both parallel to the stratification as well as across it. In part, these changes may be the result of original variations in composition, but most of them are undoubtedly due to differences in metamorphism. In the large block of country southwest of the general footwall zone of the mine, for example, cummingtonite is distributed only sparingly, and the formation is predominantly a carbonate rock; whereas in the mine and along the limb to the northeast, cummingtonite is by far the most conspicuous mineral.

The overlying Ellison formation, in the mine at least, is almost equally distinctive. Dense black micaceous slates and intermittent layers of dark quartzite identify the formation in a satisfactory way. The contact with the Homestake rocks is sharp and is a most reliable horizon in mapping structure.

The lower contact of the Homestake formation is less conspicuous, but criteria have been standardized so that close agreement exists between the lines drawn by different workers. The lowest cummingtonite or highest garnet schist (stratigraphically) marks the contact fairly well. The banded lower rocks of the De Smet-Poorman formation (grouped as one unit on account of the difficulty of drawing a precise boundary between them) form an easily recognized aggregate, though minor members are sometimes difficult to place where they can be seen only in limited exposures.

The Upper ledge (formerly termed West ledge) resembles the Homestake formation. It is almost absent within the main mine workings, but becomes

prominent both to the west and to the northeast. No ore is known in it.

The metamorphosed rocks derived from sediments in the Black Hills have been termed Algonkian by the United States Geological Survey. This usage seems acceptable, though definite correlation with rocks of distant pre-Cambrian areas, of course, is bound to be uncertain. The degree of alteration in the sediments is comparable to that in the older Huronian rocks or in the Temiskaming series of Ontario, but the granite which intrudes the metamorphic rocks in the Black Hills may prove to be of an earlier period.

Structure—The pre-Cambrian rocks of the northern hills appear on casual inspection to be merely a monotonous succession of slates, schists and quartzites, pinched into numerous tight isoclinal folds, with a prevailing strike west of north and steep dips to the east. Within the Lead area, however, where a definite sequence of formations has been established and where an unusually good key horizon exists, careful mapping has revealed a significant structural pattern into which all the related major and minor features can be rationally fitted.

Near Lead, the formations are bent into a large double fold, pitching to the southeast with the syncline on the west and the anticline on the east. The fold is about 6,000 ft. from crest to trough in horizontal section, and the limbs of Homestake formation are about 3,000 ft. apart as they diverge at the southern end of the syncline. The dimensions of the anticline are about the same.

These two folds, known as the Homestake major anticline and Lead major syncline, are complicated by numerous minor folds of several orders of magnitude. All gradations in size exist down to small crenulations, but several groups can be distinguished. The folds, ranging from 100 to 300 ft. wide in horizontal plan, are, from an economic standpoint, the most important, for it is with them that the individual orebodies of the mine are associated. On their flanks are smaller folds of a lower order, usually ranging from 5 to 25 ft. wide in horizontal plan, and they, in turn, have their sides wrinkled into little folds ranging from a few tenths of 1 ft. to 2 or 3 ft. Smaller corrugations and crenulations, seen best under the microscope, complete the sequence.

All of them, large and small, pitch to the southeast with the major structure (with a very few minor exceptions in peculiarly irregular local structures); see Fig. 1. The form and distribution of the minor folds suggests that they originated as drag folds on the sides of adjacent folds of higher order. They appear to have been created in response to shearing on the flanks of the larger structure caused by differential movement between slipping and bending layers of rock of different competency. As the compression of the region progressed, however, stress conditions changed, and minor folds apparently became involved in movements of larger units with which they were mechanically out of adjustment, and, by interference with each other, created local complexities, which in places greatly obscure the original relations. Tightly compressed isoclinal folds themselves became folded, with both limbs yielding alike to greater forces. The synclinal fold, with which the Caledonia orebody is associated, apparently was rotated into an end-on position in relation to the direction of the major regional stress, with violent consequences to itself.

The Homestake formation, with abundant carbonate and numerous thin layers of quartz sand, was an incompetent member during the folding, especially in contrast to the massive slates and quartzites of the Ellison formation that overlie it. The latter bend around the folds in relatively smooth curves, and are not involved in many of the smaller plications. Within the Homestake formation, on the other hand, the material moved like a plastic mass. On the flanks of many folds, the entire formation is sheared out, and overlying or underlying rocks are in direct contact. On the crests, great bulges exist of rock that is almost completely recrystallized to coarse radial cummingtonite, with little or no evidence of earlier texture. Intricate crumpling throughout the entire mass is graphically revealed by the thin layers of sandy quartz, which are closely wrinkled, pulled out, and rolled into pods like so much wax.

Orebodies—The factors that controlled the formation and distribution of ore are many, but each one of them is so closely related to structural features that the following discussion is largely a further elaboration of details of folds and related phenomena. The orebodies, without exception, are confined to the Homestake formation, but the distribution of the ore-bearing rocks is primarily a structural problem. The productive orebodies, as a group, are confined to the major anticlinal structure. Within it, each orebody follows its own minor fold; see Fig. 2. Furthermore, the distribution of ore within the portion of the formation included in the specific fold is controlled by conditions in the favorable rock that are closely related to factors responsible for the structure, if not actually created by them.

The folds accompanied by the orebodies vary in form as they are traced down the plunge. Locally, they narrow to bands of sheared chloritic rock; elsewhere they may thicken into large irregular bunches. A few minor folds have disappeared entirely, but thus far each one of the ore-bearing structures can be traced without the least uncertainty from exposures near the surface to the deepest levels of the mine.

A shortening of the distance between crest and trough of adjacent folds is a persistent feature down to the 2,000 level. Below this depth, however, the steeper pitch of the anticlinal arches, responsible for the convergence, flattens, and the folds have continued to the present bottom of the mine with little further change in amplitude.

On the deeper levels of the mine, the principal orebodies are bunched almost into one mining unit. This is due (1) to the disappearance of the shear zone which separated the incline and Pierce orebodies above the 2,000 level; (2) to the pinching out of the long synclinal

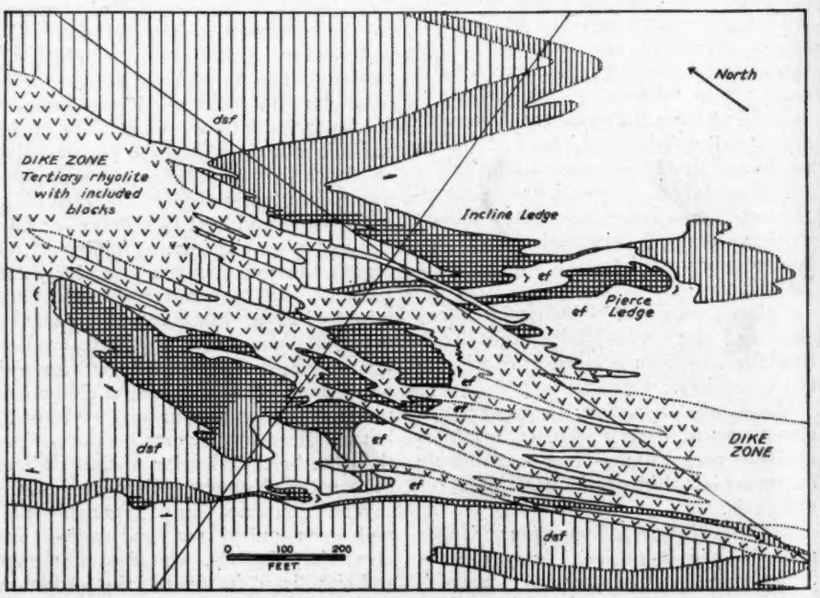


Fig. 3—Generalized geologic map of 1,850 level (same conventions as Fig. 2)

trough at the north of the main orebody on the upper levels; (3) to the reduction in width of ribs of slate and barren schist between folds; and (4) principally to the displacement of No. 4 ledge of the main orebody to the hanging-wall side of the dike zone, where it is separated only by a rib of slate from the Incline and Pierce orebodies. The area of ore on the lower levels is considerably less than on the older levels of the mine, but the reduction thus far has been largely at the expense of lower-grade ore. Little tendency for convergence of troughs and arches of folds has been observed for the last 600 ft. in depth, however, and the total area of ore on the four lowest levels has been fairly constant.

The highest folds of the central group form the Pierce ledge, made up of two pods pulled away from the main structure and connected with the limbs of their respective folds only by bands of highly sheared rock; see Figs. 3 and 4. The steeper pitch of these detached anticlines, however, causes them to approach the parent structure with depth. On the 2,150 level they join, and the pitch flattens to the average for the structure as a whole; see Fig. 1. Only the western one of the two Pierce folds is consistently ore-bearing. The eastern and higher fold is usually barren, massive cummingtonite, with only rare spots of ore. Though the two are in close juxtaposition, they are entirely separate structures and developed from different folds. The situation of the other orebodies with respect to the structure is shown in Fig. 2, which is a generalized horizontal section of the pre-Cambrian structure at the elevation of the 800 level. To make the relations clearer, the dikes have been removed and the hanging-wall block moved back into its original position.

The Incline ledge follows a well-defined anticline, from which the large fold that makes No. 1 Pierce anticline has been sheared off. The Incline orebody extends well into the syncline leading to the Old Abe fold on the east. On the west the ore is interrupted by the dikes on the upper levels, and the continuation of the ore in their footwall is called the No. 3 ledge. The largest mineralized area in the mine, known as the Main orebody, follows the No. 4 anticline, but spreads into adjacent minor structures and continues far back into the series of synclinal troughs to the north.

On many levels, good ore begins immediately under the arch of slate that wraps around the plunging anticlinal nose at the south end; but barren coarse-grained cummingtonite rock occupies this position at several places. The richest ore, however, is generally within a few hundred feet of the south end. The No. 5 ledge, which lies on the limb that extends to the northwest into the long narrow De Smet syncline, is generally low grade, but small bodies of good ore exist where minor wrinkles have created favorable conditions. The western sheared limb of the De Smet syncline marks the southwestern side of the productive ore zone, and in a sense is the footwall of the mine. The Independence ledge, which lies in an extreme southerly position, is the highest anticline of the group. Only a small amount of low-grade ore has been developed in it, or on the long limb that swings back to the north into the group of folds that comprise the wide Lead syncline. A few minor folds in this area, known as the West Ledge, are mineralized, but very little ore of commercial grade has yet been found in them.

The continuation of the Homestake formation to the north and east from the main zone of orebodies contains only a little ore, in relatively unimportant bodies at intervals until the complicated structures comprising the Caledonia ledge are reached. This puzzling orebody is an anomaly in the district, in that the ore occurs in a syncline. The structure is overturned and doubled back on itself, however, in such manner that plunging arches are created, and the minor structures the ore appears to follow are essentially anticlines. The underlying garnet schist of the De Smet formation forms both footwall and hanging wall, and even lies over the minor arches. The Homestake formation in the syncline and its central core of Ellison slate are completely pinched off from the continuous limb, which swings in fairly smooth curves to the north. In depth, the ledge narrows as a result of the disappearance of thick minor folds, which duplicate the formations on the upper levels; but a strong band of sheared Homestake formation still continues in synclinal relation to the enclosing walls. Its course in depth is difficult to predict, but it can confidently be expected to be complicated.

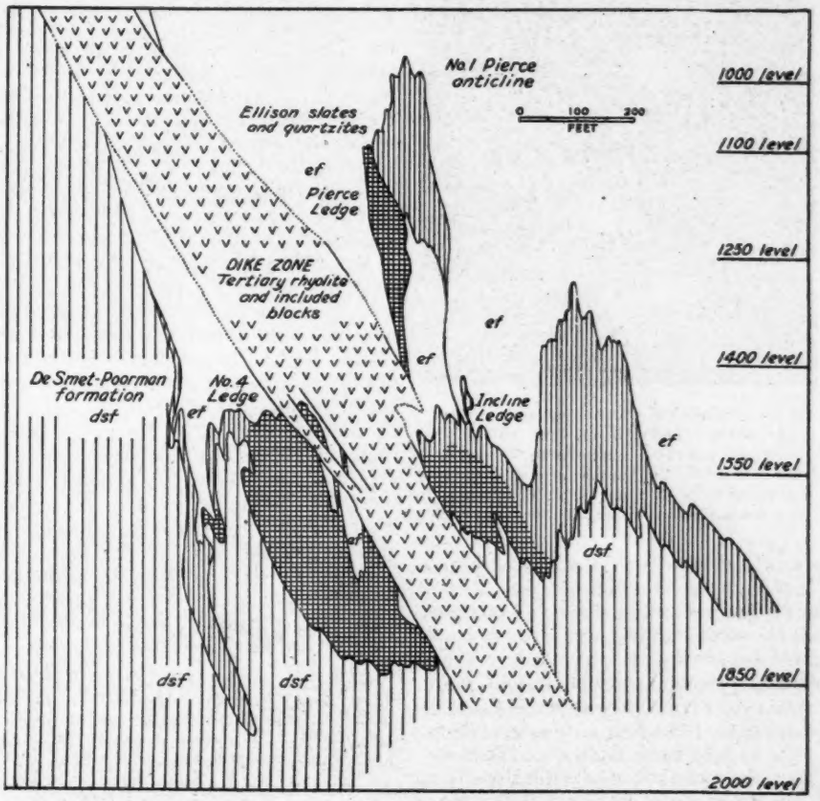


Fig. 4—Inclined section normal to plunge of folds (same conventions as Fig. 2)

Mineralization—Each of the major geologic episodes of the region is reflected in the minerals of the Homestake ores. The sedimentary material is represented by the iron-magnesium carbonate (sideroplesite) and by the more abundant sandy quartz layers, which survived merely with recrystallization of the original material. The regional metamorphism is responsible for the cummingtonite—the most striking gangue mineral in much of the ore—and for chlorite, biotite, and garnet, which are much less conspicuous components. Upon these rock minerals was imposed the hydrothermal metaporphism to which the gold is attributed. New elements were introduced with it, and new mineral combinations in the rock were created. White quartz in conspicuous gash veins and irregular masses marks the centers from which

Fig. 5—Polished surface of high-grade ore from 2,600 level, in chlorite-cummingtonite schist with quartz, arsenopyrite in coarse crystals, and pyrrhotite in fine lines and bands following the texture of the rock

alteration and gold seem to spread. Coarse-grained ankerite occurs locally in the quartz, but other gangue minerals are developed almost exclusively in the enclosing rocks. A chlorite (probably daphnite), with a distinctive light-green streak, is characteristically developed in Homestake formation in the immediate walls of the quartz bodies, and it penetrates the rock for considerable distances, even beyond the limits of ore. The hydrothermal chlorite and carbonite can generally be distinguished from the corresponding rock minerals by textural or color features and by their slightly different indices of refraction. Arsenopyrite in coarse crystals is richly developed in the chloritized rock on the margins of the quartz bodies and in inclusions of similar rock within the quartz. Pyrrhotite, the most abundant sulphide, is widely distributed in small grains and in streaks throughout the rock, usually faithfully conforming to the lamination and other textural details; see Fig. 5. Gold, the latest of the gangue and metallic minerals to form, occurs most prominently in rock that is green with the hydrothermal chlorite (the "talc" of the miners). Rock with abundant arsenopyrite and chlorite on the margins of the quartz masses or within the quartz bodies consistently gives highest assays. The arsenopyrite itself carries 2 or 3 oz. gold per ton, but rarely contains visible gold. Its presence, particularly with chlorite, is a reliable indication of ore of the best grade.

The quartz masses, with which the gold is most strikingly associated, occur in a variety of forms. Vein-like bodies, a few feet wide, may extend across the formation, on systems of cracks determined by the folding. Large, lenticular masses are locally developed in shear-zones between folds or along cusps where the formation pinches out. Saddle-shaped bodies at the crest of folds, particularly at the Ellison contact, are not uncommon. The quartz in this form is far more abundant in the ore and in the Homestake formation than elsewhere. Large bodies, however, in places break across the contact into the Ellison slates and quartzites. In these rocks, the quartz is absolutely barren. Sulphides, chlorite, and gold in the rock on the margins and in inclusions end abruptly at the contact where the slate begins.

Massive carbonate rock of the Homestake formation is rarely ore bearing. The presence of cummingtonite, from which hydrothermal chlorite is most readily formed, is probably essential for the precipitation of gold. On the other hand, the massive tough rock composed of an aggregate of coarse radial cummingtonite crystals is generally barren. The most favorable rock appears to be a cummingtonite schist with numerous crumpled layers of sandy sedimentary quartz, probably due to the increased permeability the sandy layers afford.

The quartz appears to be chiefly of replacement origin. Much work still remains to be done, however, before all details concerning its distribution and emplacement are understood. Inasmuch as the introduction of gold is closely associated with the formation of the quartz, these features offer a profitable field for continued investigation.

The latest mineralization, in the rocks of the mine, is obviously of very different character. It consists principally of veins of calcite and much smaller amounts of other minerals which have formed along fractures that break the rhyolite as well as the older rocks. Pyrite is disseminated in fine grains throughout much of the rhyolite, and also occurs as sprinklings of small crystals on calcite in vugs. A few narrow stringers of galena and sphalerite, mineralogical rarities, are probably related to this late mineralization. The one specimen of telluride from the mine, described by Dr. W. J. Sharwood, was from such an occurrence. Fluorite and amethystine quartz are also found with these minerals, and all can properly be attributed to relatively shallow and feeble Tertiary mineralization later than the dikes.

Origin—The Homestake orebodies have been considered by the majority of geologists who have studied them to be of deep-seated origin and of pre-Cambrian age. The mineral assemblage and textures, the remarkable uniformity in character of ore from the surface to a present lowest workings, the interruption and displacement of the orebodies by the rhyolite dikes, the presence of fragments of quartz and arsenopyrite in rhyolite breccias, the occurrence of detrital gold (as well as later introduced gold) in the Cambrian conglomerate and sandstone, and the contrast between the Homestake ore and the Tertiary siliceous gold ores in the northern Black Hills are among the arguments that force acceptance of pre-Cambrian origin.

The hypothesis that the ores were of Tertiary age and related to the rhyolite intrusives has been warmly supported by a few geologists. The distribution of rich ore with respect to the rhyolite dikes, the richness of orebodies in blocks within the dike zone, the occurrence of gold ores of unquestioned Tertiary age in the overlying Cambrian dolomites,

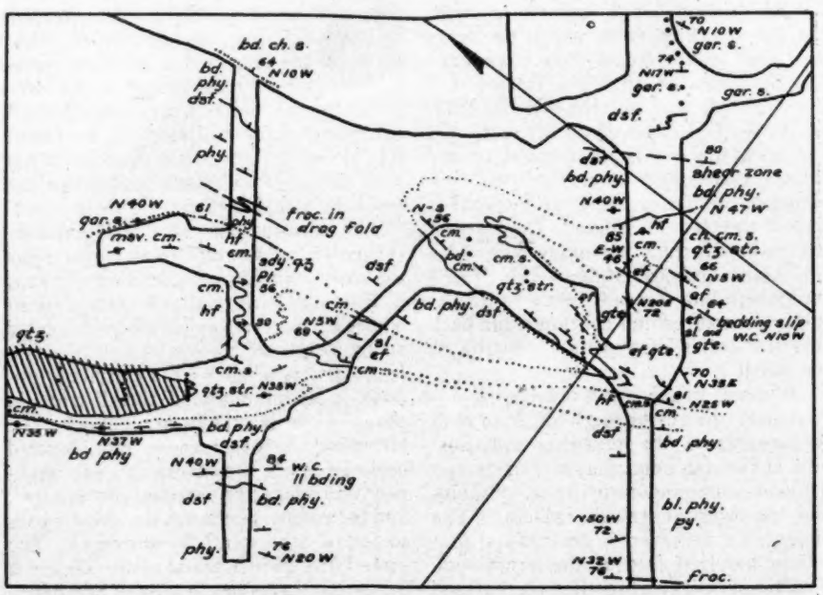


Fig. 6—Portion of detailed geologic map of the 1,700 level

Drifters and pluggers at work in the mine

the presence of gold in some pyritic concentrates from the rhyolite dikes (about 0.1 oz. per ton of pyrite), and the occurrence of arsenic in both Homestake and Tertiary ores are the major arguments that have been advanced. The points made are indeed suggestive, but on careful analysis none of them is convincing or can stand against the opposing evidence.

The ultimate source of the solutions from which the gold was derived is unknown. The evidence indicates, however, that it was probably deep-seated and was tapped only by a few outlets along specific structures. Channelization of rising solutions along relatively permeable rock in the accessible folds is believed to be responsible for the localization of the ore. The arches of dense Ellison slate over the plunging anticlines of Homestake formation, the intense crumpling of the somewhat brittle layers of sandy quartzite in the Homestake formation, and the incipient fracturing related to the folding are all significant factors in providing the channelway and confining the gold to it. Furthermore, the rocks of the Homestake formation afford conditions favorable for alteration by the hydrothermal agents and for the precipitation of gold. The remarkably selective replacement in the Homestake beds is a fact of observation, though the full explanation is perhaps still to be given. The presence of cummingtonite, which appears to be necessary for the formation of chlorite, and the presence of chlorite, which certainly was an important factor in the precipitation of gold, are probably necessary mineralogical conditions for ore.

Geological work—Our present knowledge of the geology of the northern Black Hills and of the Homestake orebody is the result of the efforts of many workers. The early studies of S. F. Emmons, C. R. Van Hise, N. H. Darton, T. A. Jaggar, and others established the major features of the region before the close of the nineteenth century. The ore deposits received less attention, but J. D. Irving's important papers on the siliceous gold ores of Tertiary age stand high among the notable contributions of the time.

The geology of the Homestake orebodies was first systematically studied in 1920, by Sidney Paige, of the U. S. Geological Survey, in collaboration with J. O. Hosted and L. B. Wright, geologists for the Homestake company. Their results were published in 1923 in papers in *Economic Geology* and in *Engineering and Mining Journal,* respectively, and later in a bulletin of the Survey. They first recognized that the ore-bearing rock was a definite folded formation derived from a carbonate bed, of sedimentary origin, which they termed an impure dolomite. The major features of the complex folds of the mine were clearly outlined by them, and many significant relations between ore and structures were pointed out. Hosted and Wright, however, differed from Paige in attributing the gold to solutions derived from the Tertiary intrusives, whereas Paige considered the ore deposits to be of pre-Cambrian age and of deep-seated origin, though he suggested that some additional gold might have been added by the Tertiary mineralization. In later papers, Wright further elaborated his arguments in favor of the hypothesis of Teritary orgin.

More recently, J. P. Connolly, Russell Gibson, John K. Gustafson, and Arthur B. Yates have made valuable contributions to knowledge of the Homestake geology. Connolly's comparisons between the mineralogy of the ores in the schists and the siliceous gold ores of the Black Hills have added convincing evidence in support of the pre-Carbrian origin of the Homestake deposits. Gustafson made a thorough study of the rocks and minerals of the Homestake formation, and distinguished with precision between minerals of the various stages of the alteration from sediment to schist and finally to ore. He established the sequence of metamorphic and ore minerals, and related the changes to the complex geologic history of the district. A. B. Yates, while he was on the geologic staff of the company, mapped portions of the mine with the detail and exactness necessary for effective application of geology to operating problems. His careful work on structure and on distribution of ore has been of outstanding usefulness.

Work on the Homestake geology is progressive and will probably continue to yield new ideas and new problems as long as the mine is accessible. Steady effort is made to record all significant facts and to improve in methods of interpreting and utilizing them. The geology of the mine workings is mapped on a scale of 50 ft. to 1 in. Formations, structures, mineralization, grade of ore, and outlines of orebodies are recorded with appropriate symbols and colors in the detail found to be necessary. Samples of such maps are shown in Figs. 6 and 7, but, of course without the colors employed to emphasize distribution of formations and ore. Simpler maps and sections, less obscured by data but in close agreement with the observed details, are prepared for use of the operating department.

Geologic work at the Homestake, where no immediate pressure exists to maintain ore reserves, is on rather a different basis from such work in most properties. The standard method of development by a hanging-wall drift with crosscuts on pillar lines is admirably suited for first exploration of new levels. The intricate structure of the orebodies and enclosing rock, however, makes it essential to have geologic facts exactly recorded and understood, particularly to insure complete development of each orebody, to aid in clean mining, to pick up ore behind dikes and in minor wrinkles, and to develop the more remote ledges most economically. The immediate duty of the resident geologists is at all times to have accurate information concerning the orebodies available in effective form for the use of the staff in current operations. The value of a thorough understanding of the larger aspects of the problems is well appreciated, however, and with the cooperation of all who follow the ore constant advance in geological knowledge of the mine is being made.

Shrinkage, square-set, draw-hole, cut-and-fill mining methods are used at Lead for the extraction of the ore, the hard and tough and abrasive character of which necessitates use of heavy blasting charges, large timbers for chute construction and other purposes, and unusually sturdy mining equipment. An uncommon feature of ore transportation underground and on the surface is the retention of compressed-air locomotives, the mechanical design and maintenance of which have been perfected so that accident hazards have been reduced to a negligible minimum. Fatalities underground are extremely rare, partly because two-thirds of the mining force is American born, and because all workers must speak English; partly because of the success of safety-first methods. The per-ton cost of mining operations is low. Apart from results in the older and caved portions of the property, the addition of rock to ore is negligible in amount. Mining methods are therefore appropriate as well as economical. More important than sound technical practices and efficient equipment, however, in the operations of a large property, is the attitude of those in charge toward certain fundamental practices, without which continued success cannot be achieved. Homestake results are due in no small measure to the fact that the mine is a model of order and cleanliness.

A. J. M. Ross
Mine Superintendent

Ore Extraction and Transportation

Operations in the Homestake mine are governed to a marked degree by what was done before the present staff was in charge. Twenty years ago the levels above the 1,100 still had considerably more than 50 per cent of the ore in place. Levels between the 1,000 and 1,700 were then being opened and developed. Stopes, pillars, haulage drifts were being cut out, and a large percentage of the ore sent to the mills came from this part of the mine (1,100 to 1,700 ft.).

Although some operating details might not now meet with unanimous approval, I think, as a whole, that the methods of mining as laid out 20 years ago were correct; and that, with the modifications introduced, they are still correct. The bearing that the work done many years ago has on present-day operations may be estimated when it is realized that over 87 per cent of the ore sent to the mills during 1930 was mined above the 1,700 level.

Homestake ore—hard, tough, and exceedingly abrasive—stands well until a certain stage is reached in mining operations. At this point, regardless of close backfilling, practiced extensively, the walls crush and the pillars become "heavy" ore to mine. When mined in the shrinkage stopes the ore breaks very large, so large that in the days when all shrinkage-stope ore was mucked on the sill floor, one "blockholer" was needed to drill and break the large boulders for two muckers. Sometimes a blockholer could break boulders for more than two muckers, but the recognized rule was one blockholer for two muckers.

In some respects a hard, tough ore is a help in mining large orebodies, such as are mined in the Homestake; but (1) many holes must be drilled to make room for one square-set of timber; (2) heavy charges of dynamite must be used to break the holes; (3) large timber must be used to withstand the impact during blasting; (4) light burdens only can be placed on holes in shrinkage stopes, otherwise large boulders are buried and must be drilled when they reach the chute; (5) boulders, which in most mines can be broken with a hammer, must be drilled and blasted; (6) chutes must be constructed of heavy material; (7) grizzly bars that are strong enough for most mining operations would be useless in the Homestake, and many other unavoidable costs must be met because of the tough and abrasive nature of the ore. The orebodies are irregular in shape. Widths between walls vary from 20 to 400 ft.

The principal mining methods in use are shrinkage, square-set, and what is known locally as draw holes. A small amount of ore is recovered by open-cut work and by cut-and-fill stoping. One large shaft pillar containing over 1,000,000 tons of ore has been caved; and although only a small percentage of this has been sent to the stamp mills, we now know that all of this shaft pillar will be recovered at a low cost and with little wall-rock dilution.

Distance between levels is 100 ft. from the surface to the 1,100 level, and 150 ft. below the 1,100 level. At present the bottom level is the 2,900 ft., where only development work is being carried on.

The method of laying out a level has been to crosscut or drift from a shaft. After the ore was struck, several drifts were driven in the ore, parallel to the walls. In this way the shape of the orebody was determined. Crosscuts were driven from these drifts through the center of the pillars and into the footwall and hanging walls. The ends of these crosscuts were connected by drifts in the barren rock. Although no regular distance from the ore was decided for driving the footwall and hanging headers, most of them are about 25 ft. from it.

At present the standard method of developing orebodies is to drive a hanging wall header far enough away from the ore to make it almost certain that at least 30 ft. of barren material is between the header and the ledge. From this hanging-wall header, crosscuts are driven through the center of the pillars and on into the footwall, to such a distance as to make sure the true footwall has been found. From the pillar, crosscuts and drifts are driven through the orebody on the walls. After the crosscuts are connected by these drifts, sill floors are then cut out on lines given by the surveyors. Manway raises, as shown in Fig. 2 (see opposite page), are cut from level to level on the footwall, and drifts are cut from these raises to the stope boundaries, which means that a stope can be entered from either pillar.

Fig. 1 is a plan of the system of mining as laid out in the main ledge. Stopes are cut out from wall to wall and 60 ft. along the walls. Pillars measure 42 ft. along the walls. The pillars are

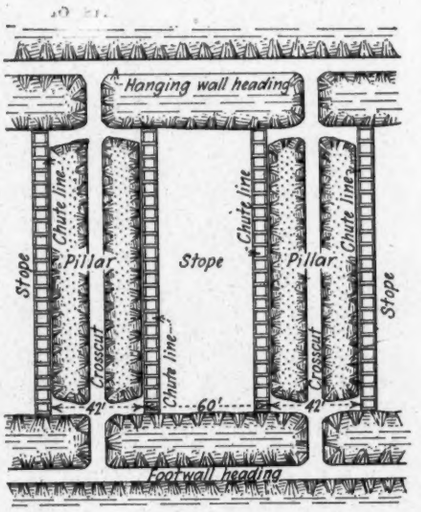


Fig. 1—Plan of sill floor operations in main ledge

perhaps somewhat larger than necessary, but the 60-ft. stope has proved to be a correct dimension in the Caledonia ledge. In the small ledges, 20 to 60 ft. between walls, the pillars have been reduced to 25 ft. along the walls, and stopes have been mined and drawn that measure 100 ft. along the walls. See Fig. 3. With this system very little loss has occurred because of dilution of ore by wall rock. All blockholing is done on top of the piles of broken ore. All blockholes drilled during the shift are blasted before the holes in the "solid" are fired.

Shrinkage stopes are usually mined until they reach a point 125 ft. above the level; this leaves a level pillar—locally known as a "crown"—of 25 ft., which has to be removed by the square-set method. In certain places underground, shrinkage stopes have been mined as high as 275 ft., with no loss of ore and no dilution with wall rock. After all broken ore has been drawn from a shrinkage stope, the filling operation is started as soon as possible. Fill is secured by drawing rock from the old glory hole through grizzlies, and tramming it to a central waste bin, which consists of a system of 6x6-ft. raises with chutes on all levels. The waste, most of which is mined on the 700 level, is dumped into this bin and drawn out on levels where needed. All known ore has been removed from this level with the exception of the Caledonia ledge. As this ledge is far from waste operations, a highly efficient and cheap method of filling is possible. When a stope is being filled, water is added to the waste, by placing a hose at the side of the waste dump in the stopes, and allowing a steady, small stream to flow down the winze while the waste is being dumped. Care must be exercised in deciding the size of the stream. A little too much moisture will wash large quantities of fine fill out of the stopes into the drifts and other parts of the mine.

After a shrinkage stope has been filled and leveled off, the level pillar is ready for mining operations. Square-set mining has been the only method found successful for this class of work. The level pillars are taken out in small sections, as experience has proved that large stopes in this class of work become "heavy" and always cave before being finished; this means a large loss of ore, beside the danger of losing men. In this class of work the first section mined, usually lying against the footwall, consists of a block of ore 60x25 ft., between pillars and out from the footwall, by 25 ft. vertically. When this has been mined to the fill in the stope above, and before being filled, the timber next to the ore still left in the level pillar is laced off with 2-in. slabs—to hold the fill in place when the next section is being mined. To start mining on the footwall side of an orebody instead of on the hanging-wall side may seem poor judgment, but this decision was made because the footwall is much weaker than the hanging wall. As a rule, to fill the level pillar stopes by car has been found too expensive, so they are filled by breaking a hole through the timber mat, then allowing the fill to "run" from stopes above. This method has the disadvantage that it loosens the fill along the pillars above, and has a tendency to increase the crushing movement that constantly goes on in pillars being mined.

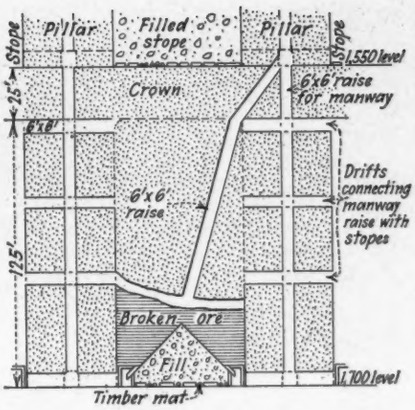


Fig. 2—Longitudinal section showing stoping method

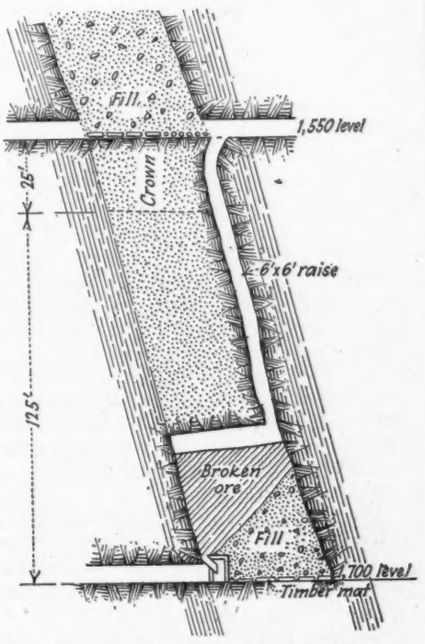


Fig. 3—Cross-section through stope in narrow ledge

The ore mined in the level pillars is trammed and dumped down the 6x6-ft. raises that were driven in the rib pillars for manways while shrinkage-stope operations were in progress. This means that the ore has to be drawn from chutes twice before being sent to the shaft; but, so far, it has proved the cheapest method.

When the level pillars have been mined out, work is started on the rib pillars. As in the level pillars, most of the rib pillars are mined by the square-set method. Where levels are 100 ft. apart, the square-set method has been successful if the stopes carried up were not too large. As a rule, the small stopes become "heavy" before they reach the height of 100 ft., requiring relief timbers, "diagonals," and other supports to keep them open and safe. With such experience in the past, the impossibility was recognized of carrying square-set stopes up to a height of 150 ft., the distance between levels below the 1,100 level. The decision was made to drive crosscuts in the pillars from the manway raise on the footwall side, through the pillars at one-half the distance between levels, and the other a short distance below the top of the pillar, as shown in Fig. 5. The crosscut near the top of the pillar is for ventilating purposes and for use as a safety

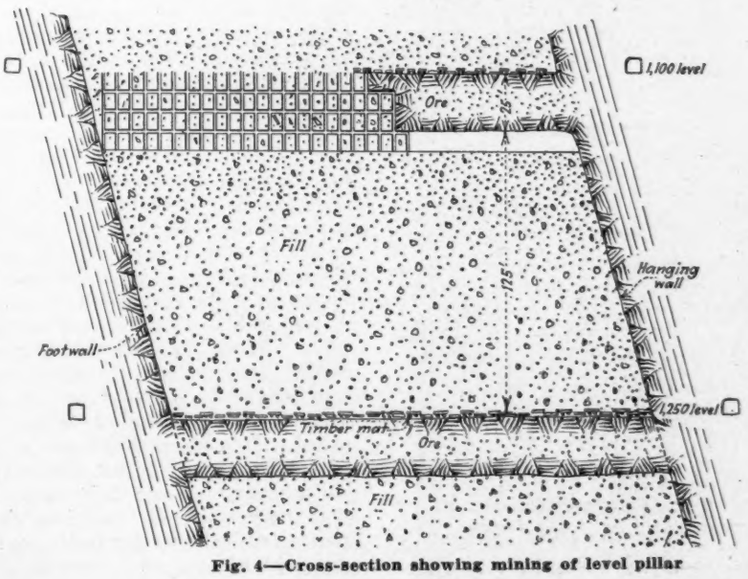
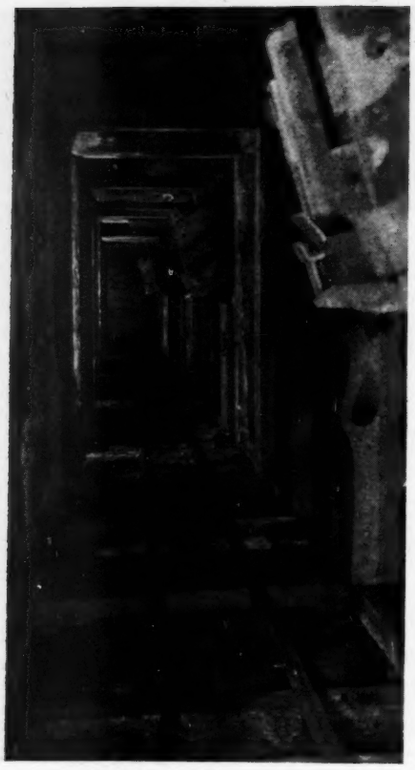


Fig. 4—Cross-section showing mining of level pillar



Track line and chutes of a shrinkage stope

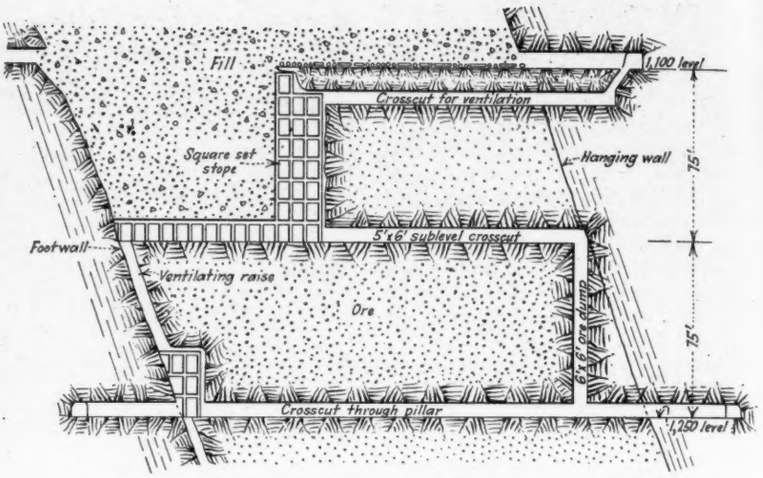


Fig. 5—Section showing details of pillar-mining operations

exit. The crosscut halfway up the pillar is the sill floor level of the stopes in the upper part of the pillar. This plan necessitates driving a raise on the hanging-wall side of the pillar through which to pass the ore mined in the upper half of the pillar to the sill floor. Thus the ore is drawn through chutes twice before being sent out to the shaft. Wherever possible, the stopes mined out in the rib pillars are filled with waste drawn from the glory hole, but, when the robbing of a pillar reaches a certain point, the entrances over the pillar stopes cave. Then the only way the stopes can be filled is by "tapping" the filled area above, and allowing the fill to run through the made opening until the stope below is filled. This work naturally caves the surface areas adjacent to the orebodies mined; but no way has been found whereby surface movement can be avoided.

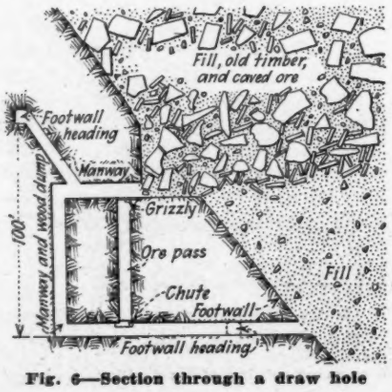


Fig. 6—Section through a draw hole

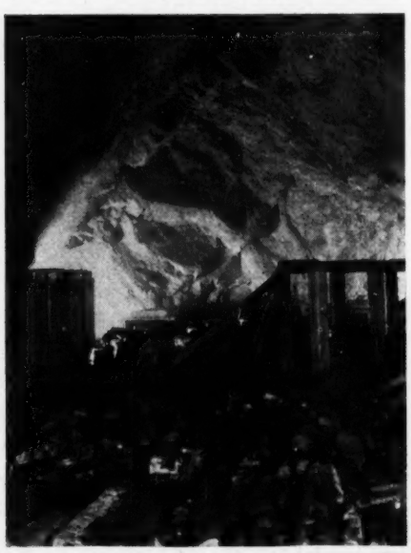
A new method of stoping in rib pillars is now being tried. This method consists of a combination of shrinkage stoping and square-set stoping. The regular square-set posts, caps, and ties are placed as in any of the pillar stopes, but no lagging is placed on the floors. The miners break down out of the solid, as in a shrinkage stope, blockhole the boulders on top of the pile, and only draw from the "swell"—the broken ore lying in the stope being used as a working platform. This method is more or less in the experimental stage, but results so far indicate that a large saving in timber and labor will result by adopting it.

During the past 15 years over 10,000,000 tons of ore has been mined by what is locally known as the draw-hole method, worked out to obtain ore in the old caved areas of the mine. This area was composed of a mixture of caved ore, immense piles of mine timber, wall rock, and some fill. The method was responsible for sending much low-grade ore to the stamp mills. Although the question has been raised as to how much profit was derived from the ore obtained through "draw hole," the operating staff is sure that the work done was profitable. Millions of tons of fill material were obtained by this method, as a great deal of sorting had to be done at the chutes. Thousands of cords of wood were drawn out of the old stopes, which were hoisted to the surface and thrown over the dumps for the citizens of Lead to haul away for their own use.

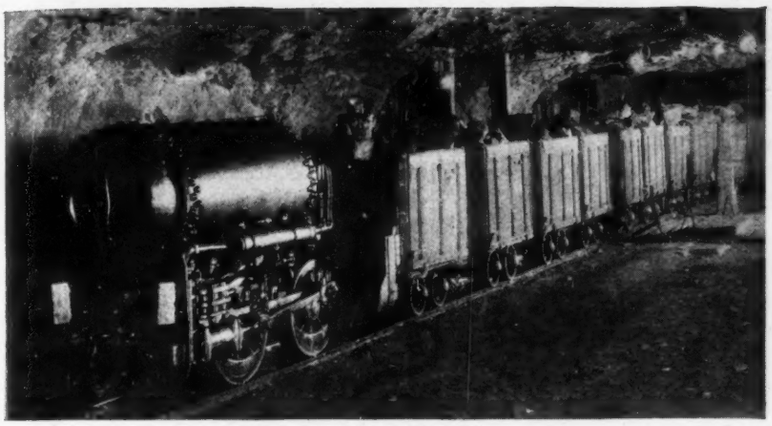
Fig. 6 shows the general plan of present-day draw holes. An underground boss designed a screen placed in front of the chute and on top of the car being loaded. This screen has been of great help. The contract chute drawers can easily separate waste from ore. For some reason the fine material drawn from a crushed area generally contains more gold than the coarse material. This does not mean that the ore crushes more easily than the waste, as we often have to drill and blast several holes, 10 ft. long, in one boulder of ore to bring it down to the grizzly. Even then the pieces will have to be drilled and blasted again before they will pass between the grizzly bars. Mining ore through draw holes will soon be discontinued, because the old crushed area is almost worked out. We will continue mining fill material by this method, as costs are low and large quantities of rock can be obtained in a short time.

Drilling in the solid ore is done with drifters. Stopers have been tried in the shrinkage stopes, but because of the nature of the ore, holes drilled "looking up" always leave a dangerous roof which is nearly impossible to dress properly. Nearly horizontal holes have proved best in mining Homestake ore.

One-inch, quarter-octagon, hollow drill steel is used for all machines. Starters have a $2\frac{3}{8}$-in. bit. Drills are changed every 12 in. when drilling is being done, and $\frac{1}{8}$ in. is the difference



Sill-floor stope ready for waste filling



Compressed-air locomotive and car train

in the size of the bit for each change. The rose bit is used for blockhole drillings. No lugs are placed on the drill steel, because all drilling machines are fitted with anvil block chucks. All drill steel is sharpened on the surface.

With the exception of a small quantity of Gellobell, used for blasting timber, 40 per cent gelatin (1⅛x8 in.) is used throughout. A little over 1 lb. of gelatin per ton of ore hoisted is consumed. Each level has a storage magazine that usually contains about 1,000 lb. dynamite, besides caps and fuse.

Compressed-air locomotives perform all haulage in the mine, and from the shaft bins to the mills. Difference of opinion may exist as to whether the compressed-air locomotive or some other type of locomotive is best suited for mine haulage. Two large items favor the compressed-air locomotive: (1) no electric wires have to be placed throughout the mine, and wherever there is a track in the mine a compressed-air locomotive can pick up loads: (2) the fire hazard of having live wires strung through timbered areas is avoided.

The cars used underground are of 20-cu.ft. capacity. End-dump and side-dump cars are in use, with a tendency to discard the former as they are worn out. The underground track gage is 18 in. and the track between the surface bins and the stamp mills is 22 in. Over 50 miles of track are in operation in the mine.

Through the B. & M. shaft about five-sixths of the ore sent to the mills is brought to the surface, and the remainder is hoisted at the Ellison shaft. The B. & M. shaft has three loading stations, on the 800, 1,100, and 1,550 levels, equipped with skip loaders operated by compressed air. No crushing is done at this shaft in the mine. At the Ellison shaft primary crushing is done with 36x48-in. jaw crushers underground, on the 800, the 1,400, and the 2,000 levels. Ore is hauled from the shaft bins to the mills in 4-ton bottom dump cars. During normal seasons the mine "makes" per minute about 400 gal. water, which is pumped in 300-ft. lifts by three-stage centrifugal pumps of 1,000-gal. capacity. The lower part of the mine can be called dry, as the only water pumped comes from near the surface through shafts, stopes, and from diamond-drill holes. A two-compartment shaft was sunk from the 2,000 level to the 2,900 level, and the only water lifted out of it to date has been the water used for drilling.

Development work and square-set stoping are done by contract. A few small shrinkage stopes have been mined by contractors, but it is hard to get miners to take a shrinkage stope on contract, because of the long period of time covered in mining and drawing the stope before final settlement. Since the War the miners at Homestake have been averse to accepting contracts that will bind them for a long period of time. Most of the shoveling and backfilling is done by contract. Contracts are let on any kind of work underground except that of drilling holes. This class of work has not proved satisfactory when done by contractors. In all work the contractor buys his powder, fuse and caps, at cost.

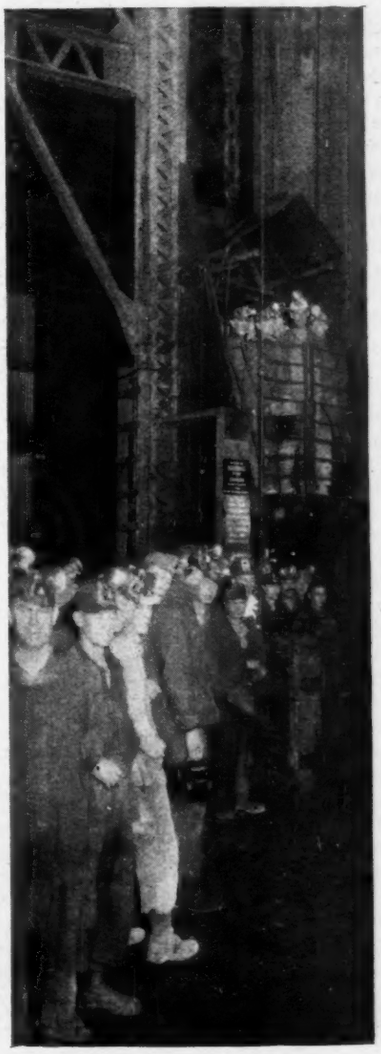
An underground employee must be able to understand orders in English and answer in the same language. About 65 per cent of the underground employees are American born.

During 1930, 1,364,456 tons of ore was delivered to the stamp mills. Of this total, shrinkage stopes produced 29 per cent; pillar, 48 per cent; and draw holes, 23 per cent.

The high percentage of pillar ore sent to the mills naturally makes for high costs, as almost all this ore is obtained by the square-set method. Nevertheless, this is good business, because much of this ore comes from the old parts of the mine, being cleaned out as rapidly as good mining practice will permit. When the old levels are mined out they can be abandoned, and large sums of money saved thereby. All experienced mining men are aware of what it costs to maintain and operate old levels in a mine that have been producing small quantities of ore for a long time.

The mine is ventilated by means of a 7x14-ft. air shaft, at the top of which a 250,000 cu.ft. per minute exhaust fan is in operation. The air current can easily be reversed by a system of doors in the fan house. A 60,000-cu.ft. auxiliary fan is in operation on the 1,850 level at the Ellison shaft. Rock temperatures are low, compared with most mines. On the 2,300 level the rock temperature is about 57 deg. F.

Nothing particularly new is to be noted in the mining methods employed. They have been used at the Homestake and in other mines for a long time. These methods must be nearly correct, for the following reasons: (1) fatal accidents are comparatively uncommon; (2) costs are low; and (3) to mine 100 per cent of the ore between levels is a regular procedure, as reported by the mine engineers in the annual report of ore blocked out. Outside the mining in the caved and old part of the mine, the loss due to dilution of ore by the addition of wall rock is almost nil.



Medical Care

One of the destructive fears dogging the steps of man is that of impending disease, with its train of suffering and unhappiness. Extra expense for medical care, hospital service, and medicine at a time when income is reduced or perhaps completely cut off has forced many a useful, independent member of society to become a public charge. What this mental hazard is costing industry in reduced efficiency is difficult to estimate, but industry is recognizing that the removal of this disorganizing fear and its demoralizing influence is in itself of great economic value. The Homestake company, for more than fifty years, has given the question earnest consideration and has set an example worth study and emulation. Free medical service to all employees and their dependents, a modern hospital with a large staff of doctors and nurses, an X-ray clinic of a type rarely found outside the larger cities—these are but a few indications of a desire to encourage employee contentment and loyalty.

Dr. R. B. Fleeger
Chief Surgeon

Health Protection and Hospital Service

The Homestake company is one of the pioneers in the field of industrial health service, having had a medical department since 1877. In the early days, however, this department was not an integral part of the organization. By agreement between employees and management, a physician, agreeable to both, was selected to render certain medical and surgical services to the employees and their families. Surgical cases in the family were not included, nor were obstetrical cases or venereal diseases, for which regular fees were charged. A deduction of $1.10 per month from the employees' wages served as compensation for the physician. This deduction was continued until 1910, when the company decided to take full charge of the department. The service was then extended to include general medical, surgical, and obstetrical cases, free of charge to all employees and their dependents. At the present time, about 1,750 persons are employed by the company. With their dependents, this brings the clientele up to about 8,000.

In 1879 the first hospital was opened—a log cabin of four rooms, with one untrained male attendant. A new hospital was built in 1889—a two-story frame building, which was a great improvement, considered a fine building for its time. The present hospital, completed in 1923, with bed capacity for 25 patients, is evidence of the fact that the department is keeping up with developments in its field. This building, with equipment, represents an investment of about $125,000. It consists of a three-story brick structure, the ground floor of which houses the dispensary, a general waiting room, a suite of doctors' offices, an X-ray room, physiotherapy facilities, laboratory, record room, and rest rooms. On the second floor are patients' rooms, a ward for men, bath room, nurses' office, two operating rooms, library, sterilizing room, kitchen, and dining room. The third floor is occupied by the nurses' home, patients' rooms, supply room, linen room, and bath room. Within the past twelve months complete new X-ray equipment has been installed—a new machine of the valve-tube type, of 125-kv. capacity. Stereoscope, automatic plate changer, and other auxiliaries are included. The table is a motor-driven, tilting table, with built-in Buckey diaphragm. Equipment for bedside X-ray work is also available. All other equipment throughout the hospital is up to date and is giving satisfactory service.

The hospital staff consists of six full-time physicians, two part-time physicians, six graduate nurses, and one nurse for the dispensary. Non-professional help, including cook, maids, and janitor, brings the personnel up to nineteen employees. One part-time physician serves at the company's hydro-electric plant at Spearfish, S. D.; another at Gillette, Wyo., where the company operates a coal mine.

The service rendered includes general, medical, surgical, and obstetric cases. A distinct division is maintained between hospital cases and service rendered in the dispensary and outside the hospital, although some overlapping is unavoidable. Work in both departments is done by the same staff of doctors. All drugs, serums, and vaccines used are furnished by the company. No pharmacy is operated, however; prescriptions are filled by a local pharmacist. Meals and nursing care are furnished patients in the hospital. An ambulance is available for bringing patients to the institution, from homes as well as from the mine. It is owned by the company, and accompanied by a sufficient number of men to handle a stretcher case. In all departments of the mine and in surface plants the men are well trained in first aid and mine rescue, so that immediate and efficient treatment and prompt removal to the hospital are assured in every case of industrial accident. At least one doctor and one nurse are on duty all day and on call at night in the dispensary. In addition, all staff doctors have regular office hours.

Each applicant for work is required to pass a physical examination. Re-examination at a stated interval is not obligatory, but employees and their dependents are welcome to examination at any time, whether sick or apparently well. Work in the homes is conducted in the manner customary in ordinary private practice. In at least nine-tenths of the calls the doctor preferred is specified, and that doctor takes the call. Thus each physician to a large extent has his own practice, and becomes well acquainted with the families in his care. All cases not necessarily requiring hospital attention are cared for in this manner, generally by three doctors. The hospital is used primarily for surgical cases, and persons suffering from contagious illness are not admitted. Major fractures, resulting from industrial accidents or occurring in the families, are hospitalized. Medical cases requiring treatment that can be conveniently given in the hospital only are also admitted. Persons rooming away from home, with no provision for nursing care, are likewise treated in the hospital.

Data for 1930, an average year for the department and the last year for which complete figures are available, will give an idea of the work done. The records indicate that 11,077 calls were made in homes, and 51,085 dispensary treatments given, consisting of dressings, examinations, and prescriptions; 136 confinements were taken care of, 3,121 laboratory tests made, and 1,233 physiotherapy treatments provided; X-ray examinations totaled 710; 511 patients were fitted with eyeglasses. Of 1,033 applicants for work who were examined, 85 were rejected. Defective vision was the principal cause for rejection, with hernia second. Hospital treatment included 94 medical and 384 surgical cases, totaling 4,278 days, or an average stay in the hospital of 9.8 days per patient.

As previously mentioned, this service is free to all employees and dependent members of their families. No patients who do not come under this classification are taken. The cost to the company for operating and maintaining the medical department usually averages between $60,000 and $65,000 per year.

Gold Mining—Facts and Figures

S. D. Strauss
Assistant Editor

IN 1931, the gold mines of the world will probably produce more of their gleaming metal than they have at any time since the record years of 1915 and 1916. A conservative estimate indicates that output this year will probably be about 21,000,000 oz., compared with 20,150,000 oz. in 1930 (the A.B.M.S. 1930 world estimate of 20,460,000 oz. includes an over-estimate of more than 300,000 oz. on Russian production). Not only is the actual volume of production by gold mines greater than at any time in the last fifteen years, but the scale of profits is also greater. The depression that has spelled disaster to so many other industries has lowered production costs for this industry that obtains a fixed price for its product.

The increase in production is coming largely from Canada, South Africa, Australia, and one or two other countries. The period of lowered costs has not yet lasted long enough to encourage much so-called "marginal" production—that is, gold obtained from mines which formerly could not operate at a profit. New, large mines are contributing the increase, as well as some individual placer recovery from unemployed men working over old fields. But, if commodity price levels remain at or near their present low levels for an additional year or two, a substantial output should be realized from marginal mines.

In its excellent pamphlet on the past production of gold (Economic Study No. 6), the U. S. Bureau of Mines has exhaustively set forth the statistical history of gold from 1492 up to 1927. To go back over this ground would be unwarranted duplication. The figures and charts that accompany this article are intended only to convey an impression of gold mining at present.

The outstanding fact about the industry is that one district produces 53 per cent of the world total output. If gold were a metal found in few localities, this might not be remarkable; Sudbury, after all, produces 90 per cent of the world's nickel. But gold is scattered everywhere. Important quantities of it have been mined in every continent. No less than fifteen separate countries produced more than 100,000 oz. of it in 1930. Under such circumstances, the importance of the gold mines on the Witwatersrand, in the Transvaal, Union of South Africa, assumes its true significance. No other district produces more than one-tenth of the gold that is annually recovered from its 33 mines, stretched out along its length of 90 miles or so.

Witwatersrand production, in spite of pessimistic prophets, has been rising year after year. It will almost certainly be higher in 1931 than in 1930. With two new mines in operation, the prospects are that 1932 production will be greater than this year's. The extension of ore-bearing reef into large areas on the Far East Rand that are not now producing has been proved. All signs seem to indicate that eventually the Sub Nigel mine, which now lies isolated from the other producers at Heidelberg, will be linked to them by a solid chain of new producers.

The Witwatersrand does not have to extend its known limits, however, to find gold. Huge quantities of material containing 3.5 to 4.5 dwt. in gold per ton are known to exist in present producing ground. If costs can be cut, the life of this greatest of all gold districts will be prolonged for ten to fifteen years. On the solution of that problem, much energy and thought has already been expended. It involves consideration of other questions—colored labor, taxation, governmental aid, and in-

Table I—Average Annual Gold Production of Leading Countries

Figures given are the annual averages for five-year periods—all fine ounces

Country	1901–05	1906–10	1911–15	1916–20	1921–25	1926–30
Union of South Africa	3,726,688	6,837,230	8,742,492	8,682,555	8,698,551	10,317,181
United States*	3,878,744	4,591,342	4,556,952	3,387,511	2,368,637	2,131,523
Canada	922,729	482,172	715,667	780,537	1,334,882	1,903,988
Russia	1,113,102	1,375,726	1,313,559	536,840	561,725	800,535
Mexico	578,834	1,048,195	774,352	623,630	760,167	703,558
Southern Rhodesia	222,663	564,625	755,360	708,492	620,603	571,882
Australia	3,614,257	3,078,633	2,211,170	1,294,598	700,371	479,053
British India	523,281	523,870	553,301	511,350	416,640	367,281
Japan	116,969	158,322	215,418	241,164	255,984	317,626
British West Africa	66,571	235,876	359,917	303,887	210,235	197,144
Belgian Congo	.....	14,873	39,989	107,545	93,254	152,545
New Zealand	462,428	480,557	346,543	207,442	135,558	121,172
Philippine Islands	.....	9,085	36,612	61,696	78,027	124,606
Brazil	108,784	104,758	137,619	128,714	135,801	106,921
Peru	51,657	27,635	34,915	61,522	103,176	107,388
Colombia	121,971	149,224	186,176	280,323	203,005	58,229

* Does not include Philippine Islands.

World gold production contrasted with that of the leading individual producing country—the Union of South Africa, now producing 53 per cent of the world total

Table II—Gold Production in 1931. Estimated

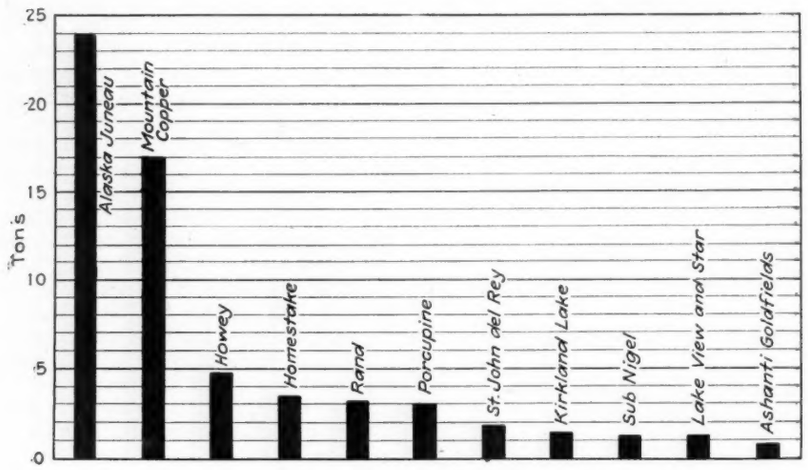
All figures in fine ounces

Country	1930	1931
Union of South Africa	10,716,351	10,780,000
Canada	2,102,068	2,750,000
United States*	2,100,395	2,100,000
Russia	932,350	1,000,000
Mexico	668,977	650,000
Southern Rhodesia	547,631	525,000
Australia	466,435	550,000
India	328,242	290,000
British West Africa	248,491	260,000
Belgian Congo	194,154	225,000
Philippine Islands	185,208	225,000
Totals	18,490,302	19,355,000

* Does not include Philippine Islands.

provements in practice. No surer step could be taken for the future prosperity of the Union of South Africa than a plan by which this material might profitably be converted into gold.

Compared with the Transvaal, Canada is still a small producer. But the Dominion has been making such tremendous strides within the last fifteen years that it has now become the world's second largest gold producer and is increasing its output at the rate of 20 per cent or more annually. The greatest factor in this increase has been the camp of Kirkland Lake, in Ontario, now second only to the Transvaal. An accompanying chart indicates the rapidity with which output is rising there—more than tenfold in ten years. Porcupine, long Canada's premier camp, has been relegated to second place. Its peak has apparently been reached, but the hope that its present output will not decline materially for several years is justified. Best of all, however, for assurance of continued increases in Canada's contribution is the number of gold mines being developed in other districts—Red Lake, northwestern Quebec, Matachewan, Michipicoten, central Manitoba, Bridge River, Sheep Creek, and Portland Canal—all are making or promise to make contributions to the total.



The number of tons of ore that must be treated to obtain one ounce of gold varies from 24 at the Alaska Juneau property to 0.85 at Ashanti Goldfields. The columns labeled "Rand," "Porcupine," and "Kirkland Lake," in this chart, represent the averages for the entire districts; the others represent individual mines

Table III—The World's Leading Gold Mines

Name	Location	Output in 1930 Fine Oz.	Tonnage Treated in 1930 Short Tons	Yield Oz. Per Ton of re
Government Gold	Transvaal	1,107,046	2,438,638	0.46
Crown Mines	Transvaal	924,298	2,905,000	0.32
New Modderfontein	Transvaal	862,506	1,811,000	0.48
Randfontein Estates	Transvaal	652,575	2,573,000	0.25
Hollinger Consolidated	Ontario	494,532	1,625,868	0.30
East Rand Pty	Transvaal	491,095	2,088,832	0.23
New State Areas	Transvaal	445,917	930,000	0.48
Springs Mines	Transvaal	408,208	836,700	0.49
Homestake Mining	South Dakota	406,000	1,364,456	0.30
Brakpan Mines	Transvaal	391,785	1,040,200	0.33
Lake Shore	Ontario	378,690	550,501	0.69
Robinson Deep	Transvaal	365,781	1,339,000	0.27
Langlaagte Estate	Transvaal	326,398	961,500	0.34
Geduld Proprietary	Transvaal	322,884	1,011,000	0.32
City Deep	Transvaal	306,425	1,157,500	0.26
Sub Nigel	Transvaal	304,915	357,200	0.85
Van Ryn Deep	Transvaal	297,602	771,000	0.38
Modderfontein B	Transvaal	293,517	840,000	0.35
West Rand Consolidated	Transvaal	290,671	1,087,000	0.25
Modderfontein Deep	Transvaal	275,251	530,400	0.52
Teck-Hughes Gold	Ontario	260,775	338,555	0.77
Consolidated Main Reef	Transvaal	258,856	733,900	0.35
Simmer & Jack	Transvaal	250,485	916,700	0.27
Modderfontein East	Transvaal	242,149	833,000	0.29
McIntyre Porcupine	Ontario	225,786	565,510	0.40
Nourse Mines	Transvaal	223,198	760,700	0.29
West Springs	Transvaal	218,054	815,800	0.27
Geldenhuis Deep	Transvaal	186,236	811,900	0.23
Durban Roodepoort	Transvaal	172,562	520,000	0.33
Alaska Juneau	Alaska	163,312	3,924,460	0.042
Rose Deep	Transvaal	155,841	733,400	0.21
Ashanti Goldfields	Gold Coast	151,666	129,379	1.17
Kilo Moto Gold	Belgian Congo	147,799	.....	....
Witwatersrand	Transvaal	145,355	659,500	0.22
New Kleinfontein	Transvaal	135,192	619,200	0.22
Lake View & Star	Western Australia	132,578	157,693	0.84
Cam & Motor	Southern Rhodesia	128,656	285,000*	0.45
St. John del Rey	Brazil	121,000	226,800	0.53
Van Ryn Estate	Transvaal	119,024	496,000	0.24
Wright-Hargreaves	Ontario	117,455	220,430	0.53
Noranda Mines (a)	Quebec	117,258	733,971	0.16
Witwatersrand Deep	Transvaal	113,906	498,000	0.23
Mysore Gold	India	101,551	213,728	0.44

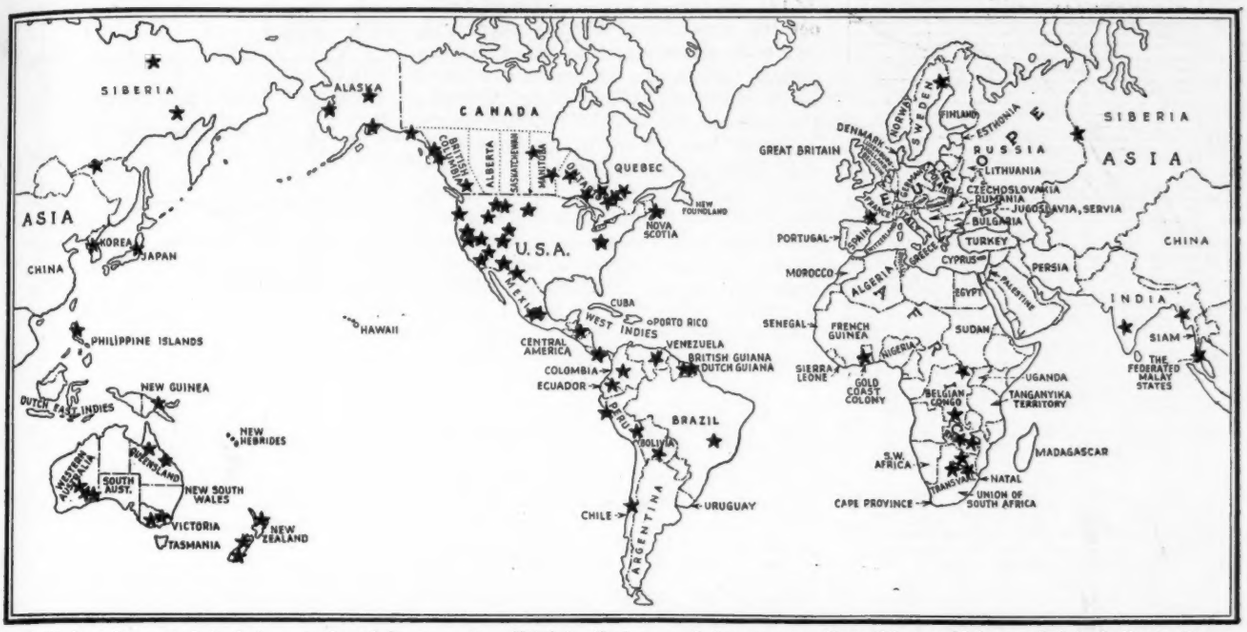
* Partly estimated. (a) Noranda is primarily a copper mine.

In the United States, long so prominent in gold production, the industry has been fading into obscurity in recent years. Cripple Creek, Goldfield, Tonopah, and other famous camps have seen their best days. New camps have not been found. Homestake and Alaska Juneau, plus the byproduct output from base-metal mines, accounted for half the country's total in 1929. But with the advent of depression and unemployment, a subdued "boom" has resulted. Lacking any one district in which to manifest itself, it has taken shape in the reopening of old mines, long dormant, and the reworking of placer diggings that had been thought exhausted. Despite a sharp drop in the byproduct recovery of gold, total production in 1930 was higher than in 1929—an indication that the gold mines made a substantial increase. A further drop in byproduct output will occur this year. In 1929, base-metal mines produced more than 491,000 oz. of gold. In 1931, they will produce barely 200,000 oz.

Australia, which once disputed with the United States for premier rank among the world's gold producers, has suffered even a greater decline in its production. Last year was the first in many that the downward tendency was halted, and even then the continent produced only 466,435 oz.—an eighth of what it did early in the century. This year a substantial rise is in prospect, and the future appears more attractive. Three major enterprises will contribute the greater part of this increase (Lake View & Star, Wiluna, and Mount Coolon), but the smaller mines are not inactive. A federal bonus, plus the advantage to be gained from the depreciation in Australian currency (which now adds 30 per cent to the value of gold), has awakened interest in the precious metal. Probably more prospectors are searching for gold in Australia's sandy wastes than in any other country. In some states, the local government is subsidizing the prospectors. Nearly all furnish milling facilities for small tonnages at cost price.

Under the influence of the Five-Year plan, which has not overlooked the chief monetary instrument of capitalism, Russia's gold output has been increasing steadily. Strangely enough, the figures given by the U. S. Bureau of the Mint in its annual report are actually higher than those claimed by the Soviet. In my compilations I have in all cases used the figures given by V. Karmashov in a recent issue of this publication. Further increases are scheduled. Whether they will be attained is another question.

The Mysore field, in India, seems to be gradually dying out. Southern Rhodesia is another British colony



Gold has been and is being produced in so many districts that a much larger map than this would be needed to indicate them all. The stars do represent some of the leading gold-producing areas, however, including some where gold is recovered as a byproduct.

which has no present prospects of improving its position. Mexico, where gold is chiefly byproduct, has had a mild rush at El Tambor, but the amount recovered there has not been large enough to counterbalance curtailed base-metal output. On the other hand, British West Africa—thanks to Ashanti Goldfields; Belgian Congo—thanks to Kilo-Moto; and New Guinea—thanks to Bulolo Gold and New Guinea Goldfields—are all on the upgrade. The last-named, in fact, is said to have the possibilities of another Rand, by no less an authority than Leslie Urquhart. In this connection, mention should be made of Panama, where the Panama Corporation is developing what Hugh Marriott claims to be a potential successor to the great South African field.

The Philippine Islands, which is being considered separately from the United States in this article, has forged steadily ahead ever since the first gold was produced under American possession. The activity of several outside companies in the Islands, as well as the continued prosperity of Balatoc and Benguet, chief local producers, is guarantee that expansion will continue.

Considered as a world entity, several trends are apparent in the gold industry:

Continued increase in the total volume, with no apparent prospect of a sharp reversal in the trend. Despite the prophesies of the League of Nations committee on gold, a rapid exhaustion of the world's gold resources in the near future does not seem probable.

Lode mines now produce not less than 90 per cent of world gold output. The only important placer deposits that have been or are being brought into production are the Fairbanks field, in Alaska; the Bulolo field, in New Guinea; and scattered areas in Montana, Siberia, Peru, and Australia.

High-grade mines are becoming few and far between. The new gold properties—such as Wiluna, East Geduld, Daggafontein, Beattie (Canada), and others—require a large amount of capital to develop and equip. "Grass-root" mines that finance themselves are not being found. If gold production is to grow, it must grow through large-scale, low-grade enterprises. Alaska Juneau has set a splendid example.

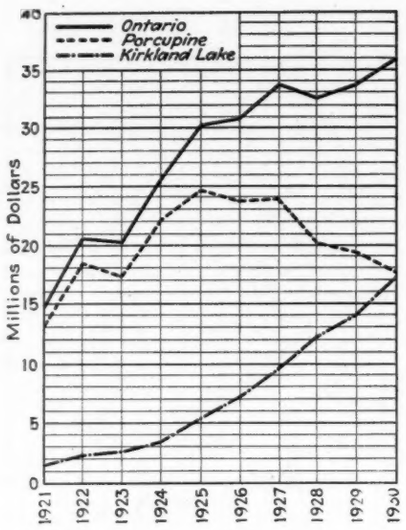
Governmental recognition of the distinctions that set gold mining apart from other industries is growing. Gold cannot be overproduced. It has a constant market at a fixed price and is a useful agent of society. Governments, realizing this, are anxious to assist gold-mining enterprises. Further advances in this direction—regardless of whether they are welcome to the gold miner or no—may be expected.

The miner is always interested in individual performances of mines. In the accompanying tables, a few figures are set forth concerning outstanding mines. At present, Government Gold Mining Areas, in the Far East Rand, is the world's largest gold producer. Its output of 1,107,046 oz. is exceeded only by three countries—the Union itself, the United States, and Canada. The mine itself covers an area of 2,633 claims and is developed through four large shafts. In 1930, the company paid dividends of 90 per cent on its capital of £1,400,000—or £1,260,000. In addition, the government, which leases the ground to the company, obtained £1,448,863 of the profit of £2,768,080.

There are 42 other mines in the world that produced more than 100,000 oz. of gold in 1930. Of these, 28 are on the Witwatersrand (if Sub Nigel is included). Among the remaining 14 mines, Canada claims six and the United States, two. Hollinger Consolidated was the largest producer outside the Transvaal in 1930, ranking fifth if the Transvaal is included. Lake Shore, which has recently put a new mill addition into operation, will undoubtedly surpass Hollinger this year.

The mine that has, so far as records indicate, produced to date more gold than any other in the world is the Crown Mines, which, to the end of 1930, had 20,461,740 oz. to its credit. Randfontein Estates was second, with a total of 14,019,021 oz. East Rand Proprietary is credited with 13,614,769 oz. Homestake, the operations of which are so fully described in this issue, is the leader among mines outside the Witwatersrand, with 12,325,544 oz.

Alaska Juneau is the lode mine that handles the largest annual tonnage of ore. Although, because of its low grade, the output of gold is small compared with some other mines, its tonnage of about 4,000,000 short tons annually is 25 per cent greater than Crown Mines, its chief competitor. Alaska Juneau has also the distinction of being the lowest-grade gold lode mine in the world. Chart No. 2 illustrates clearly what handicaps the company has overcome in reaching dividends (the first, of 10c. a share, having been paid in February of this year). The only mine which has a comparable number of tons to crush to obtain one ounce of gold is the Mountain Copper property, in Shasta County, Calif. In view of the small tonnage handled at the latter—about 600 tons daily—the record achieved there is truly remarkable, for the ore yields an



In ten years, production of Ontario's gold mines has more than doubled—thanks largely to the developments at Kirkland Lake, now the world's second largest producing area

average of only $1.20 in gold per ton.

Probably the highest-grade gold mine of any size in the world is the Ashanti Goldfields property, on the Gold Coast, where run-of-mine ore assays better than 1 oz. of gold to the ton. The Balatoc property, controlled by Benguet Mining, in the Philippine Islands, averages almost as well, and, as mill capacity is being doubled there, will soon be a real rival to Ashanti. Sub Nigel is the highest grade of the mines that handle more than 1,000 tons of ore daily.

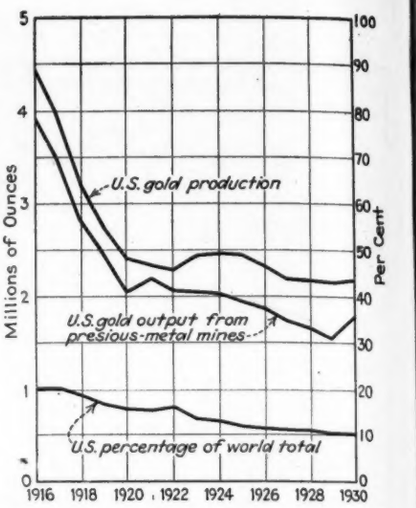
The lowest cost, per ton of ore handled, was that achieved at Alaska Juneau, which reports operating expenditures of $0.627 per ton of ore. Translated into gold, however, Alaska Juneau is far from being the world's lowest-cost producer. It costs the Modder Deep mine, on the Rand, only $7.42 in operating expenditures to turn out one ounce of gold, worth $20.67. Teck-Hughes reported costs of only $7.52 per ounce in the year ended Aug. 31, 1930, and may well have surpassed Modder Deep in this respect this year. Mountain Copper comes closest to rivaling Alaska Juneau in per-ton costs, with charges of $0.817. The list given in Table IV is an incomplete one and includes only outstanding mines.

Crown Mines stands first in another respect—that of the development footage driven. In 1930 this remarkable mine drove no less than 128,056 ft. of new development headings, or 4.4 ft. for every 100 tons of ore treated. Randfontein Estates drove 108,613 ft. of new workings. Hollinger Consolidated ranked first outside the Rand, with a total of 68,139 ft. driven in 1930. On the basis of 1,625,868 tons of ore produced, the average was 4.4 ft. for every 100 tons of ore.

The average varies greatly with the type of deposit. In the Transvaal as a whole, the new development footage at producing mines in 1930 was 1,258,341 ft., compared with treatment of 32,141,336 tons of ore—a ratio of 3.9 ft. per 100 tons of ore. On the other hand, in a wide orebody such as that at Alaska Juneau, which can be amply developed by drilling and widely-spaced laterals, the ratio is low (13,185 ft. for nearly 4,000,000 tons of ore or an average of only 0.34 ft. per 100 tons). Perhaps the greatest amount of development, on the basis of ore produced, done by any producing lode gold mine is performed at the Transvaal Gold Mining Estates property, in the Lydenburg district, Transvaal. This property, which has been in operation for many years, performed 39,883 ft. of new work during the fiscal year ended March 31, 1930. As 172,280 tons of ore was milled, the ratio was 23 ft. for every 100 tons milled.

The most profitable gold mine in the world in 1930 was the largest—Government Gold Areas, which operated at a profit of £2,768,080 (or $13,452,869). It was not, however, the mine which paid out the greatest sum in dividends to its stockholders. New Modderfontein, another one of the giants of the Rand, distributed £1,855,000 (or $9,015,300). Government Gold, which pays so large a percentage of its profits to the Union government, was nevertheless able to distribute the neat total of £1,260,000 ($6,123,000), to rank second on the list. All told, sixteen mines in the Transvaal paid dividends of more than £100,000 each. Eight others made smaller payments. The total distribution for the 24 companies in 1930 was £8,641,309 ($42,011,342) in dividends, out of a declared working profit of £13,661,498 ($66,394,910).

Compared with these figures, the profits and dividends of other gold mines seem small. In Ontario, Canada's chief gold-producing province, dividend disbursements totaled $11,133,210 in 1930 and included five mines each of which distributed more than $500,000. The largest was Hollinger, with a total of $3,444,000. Lake Shore, with $3,000,000, and Teck-Hughes, with $2,872,286, are two other large contributors. Noranda Mines, copper-gold producer of Quebec, paid out $5,599,430, but this can hardly be attributed to gold mining, as copper is still the predominant metal



Production of gold from U. S. gold mines declined sharply from 1916 to 1929, while byproduct output increased. In 1930 the trend was reversed.

in the ore. Premier Gold, which obtains about equal revenue from its gold and its silver output, paid $1,200,000.

In the United States, the only large dividend payer for which figures are available was Homestake, with a disbursement of $2,009,280. Two important dredging properties—Fairbanks Exploration, subsidiary of U. S. Smelting, and Yuba Consolidated, in which New Consolidated Gold Fields has a large interest—do not publish their dividend payments, although they are undoubtedly large. Alaska Juneau paid no dividends in 1930, but is now paying at the rate of about $600,000 annually. No other gold mine in the United States pays more than $500,000 a year.

None of the big Mexican gold producers can be classed as gold mines. In South America, St. John del Rey falls short of the £100,000 mark, having distributed £71,454 in 1930. Of the African mines outside the Transvaal, Ashanti Goldfields led in 1930 with its distribution of £187,500. Cam & Motor, leading Rhodesian mine, paid £150,000. In British India, Mysore Gold was able to declare dividends totaling £107,970. Total Indian gold dividends were £267,356. None of the Australian mines even approached £100,000, and only three companies paid dividends at all.

Table IV—Low-Cost Gold Mines

Figures obtained from most recent annual report available

Company	Location	Ore Handled, Short Tons, Per Annum	Yield, Oz. Per Ton	Costs, per Ton of Ore*	Costs, per Oz. of Gold*
Alaska Juneau	Alaska	3,924,460	0.042	$0.627	$15.06
Ashanti Goldfields	Gold Coast	124,200	1.17	9.65(a)	8.29(a)
Balatoc	Philippines	52,587	1.16	10.83	9.34
Government Gold Areas	Transvaal	2,438,638	0.46	4.02(a)	8.85(a)
Homestake Mining	South Dakota	1,364,456	0.30	3.13	10.53
Lake Shore(d)	Ontario	467,648	0.67	5.85	8.60
McIntyre Porcupine(c)	Ontario	558,115	0.40	4.56	11.40
Modder Deep	Transvaal	530,400	0.52	3.85(a)	7.42(a)
Mountain Copper(b)	California	202,164	0.061	0.817	13.41
New Modder	Transvaal	1,811,000	0.48	4.13(a)	8.68(a)
Teck-Hughes(e)	Ontario	340,675	0.77	5.78	7.52

* These costs are based on actual operating expenses and do not include income taxes, depreciation, or royalties. They also exclude, wherever possible, expenditures on outside properties.

(a) Translated into dollars at the rate of $4.86 per £.

(b) Annual report not available. Based on returns for March, 1931, applying to low-grade gossan deposit only.

(c) Year ended March 31, 1931. (d) Year ended June 30, 1930. (e) Year ended Aug. 31, 1930.

The News in Brief

Reorganized Phelps Dodge Staff. As a result of the merger of Calumet & Arizona and Phelps Dodge, leading copper producers of the Southwest, changes have been made in the operating personnel at the properties. Appointments effective Oct. 1 include H. A. Clark, manager of the Douglas smelters; J. P. Hodgson, manager of the Bisbee Mines; George Jay, western traffic agent at Douglas; J. Owen Ambler, smelter superintendent; C. H. Cole, in charge of metallurgical investigations; H. M. Lavender, mine superintendent; H. J. Bishop, chief clerk, E. C. Robinson, chief engineer, and H. L. Gooding, master mechanic at Douglas; Dr. R. M. Ferguson, chief surgeon, L. R. Buell, chief clerk, and A. C. Reifsnider, master mechanic, of the mining division. The C. & A. hospital has been closed, all work being confined to the Copper Queen hospital in Bisbee. Mining, mechanical, and supply departments will be at Lowell; the mine manager's and accounting departments, at Bisbee.

■

Copper Range Cuts Wages. A further reduction of 17½ per cent in wages and salaries, effective Oct. 1, has been made by Copper Range, operating near Painesdale, Mich. A minimum wage for married men has been adopted, and no lower wage will be paid. The reduction is the fourth since the depression started. The mines and mill are working four days a week.

■

U. V. X. Resumption. Condition of the copper market does not justify resuming operations at the United Verde Extension property, Jerome, Ariz., according to George Kingdon, general manager, but the company will probably reopen on Nov. 1 to relieve unemployment during the winter months. Copper produced will be stored at the smelter. No cut will be made in the wage scale, but only men employed at the time of closing will be taken on when operations are resumed. J. R. Finley, of New York, has been employed by the state of Arizona to survey the property in connection with tax-valuation suits.

■

Coppermines Costs Discussed. A stockholders' committee of the Consolidater Coppermines Corporation has published a new notice to stockholders in which certain aspects of the affairs of the company are discussed. In particular, reference is made to the statements regarding production costs contained in the report of the company, which operates at Kimberley, Nev. "In the latter [the 1930 report] of the cost of producing copper was given as 8.886c. per pound before charging against that cost anything for *development expense*, depreciation, or depletion. The two items named last are not always considered in arriving at the per pound cost of copper, but to omit development expense in a statement to a body of stockholders largely unfamiliar with the technical aspects of mine accounting, fails to give the information to which stockholders are entitled . . . The cost of development is a necessary and inescapable expense and must be paid for. The usual and proper practice is to charge it against the developed ore as the same is mined. . . . As we have previously pointed out, the true cost of producing our copper in 1930 was above 11c. per pound (without adding anything for depletion)," the notice states. It is signed by Thomas Bardon, vice-president of Shattuck Denn, C. K. Blandin, and R. W. Higgins.

■

Copper Tariff Hearing. The U. S. Tariff Commission will conduct a hearing on a tariff for copper on Oct. 28, in accordance with a resolution introduced in the Senate.

■

Northern Peru Closes. Operations have been completely suspended by Northern Peru Mining & Smelting at its properties near Trujillo, Peru, except for the Pataz gold unit. The company, second largest copper producer in Peru, normally emyloys 4,000 men and can produce as much as 1,000 short tons of copper monthly. It is a subsidiary of American Smelting & Refining.

■

Sherritt Gordon Output. Production of copper by Sherritt Gordon, new Manitoba producer, was 1,990,000 lb. in August. The mill handled an average of 880 short tons daily, although rated capacity of the one unit in operation is only 600 tons. Ore averages 3.7 per cent copper and extraction is 95 per cent. Costs, including smelting charges at the Hudson Bay plant, refining, and transportation, are put at $4.15.

□

Roan Smelter Progress. Construction of the new Roan Antelope copper smelter will probably be completed in November. Production from three concentrator units in September was 6,660 short tons of concentrate averaging 55.75 per cent copper from 153,000 tons of ore averaging 3.27 per cent copper. This indicates that each of the concentrator units is handling 1,700 tons daily, compared with the rated capacity of 1,000 tons.

■

Boleo Copper Damaged. Recent hurricanes along the west coast of Mexico did considerable damage, estimated at more than 1,000,000 pesos, to the properties of Boleo Copper, at Santa Rosalia, Baja California. Repairs are expected to be completed by the end of October. The railroad suffered the greatest damage.

■

C. V. Bob's Trial Starts. On Oct. 6 trial of Charles V. Bob, mining-stock promoter, was started in New York City. He is being tried in connection with an alleged fraud of $6,000,000 through the sale of stocks in his companies, chief of which was Metal & Mining Shares, Inc. F. C. Russell, treasurer of the company, is also on trial. The hearing, in the federal district court, is likely to last six weeks.

Yuba Permit Extended. Yuba Consolidated Gold Fields has until Dec. 31, 1934, to continue gold dredging in the Yuba River, near Daguerre Point, Calif. Permit for this work was issued April 5, 1927, and was to have expired on Dec. 31, but the War Department extended the period in which operations might be continued. The company has yet to dredge 9,000 ft. of the 500-ft. south channel of the river.

■

Lake Shore Body Wide. On the 2,200 level of the Lake Shore mine, at Kirkland Lake, Ont., now leading producer in the Americas, development has shown the orebody to average 66 ft. in width over a 150-ft. stretch. At another point, 500 ft. east, it is 30 ft wide. The orebody is being developed on all levels between the 2,200 and the 2,950. Adoption of flotation treatment, to improve mill extraction, is contemplated.

■

Big Missouri Mill Down. Milling operations at the Big Missouri silver-gold property, in which Consolidated Mining & Smelting has a controlling interest, have been suspended. A 100-ton pilot plant had been built to test the ore at the mine in the Portland Canal district, British Columbia. Whether the reason for closing was the conclusion of the tests or unsatisfactory results is not known.

■

California-Alder Gulch Progress. Bay City Shovels, Inc., of Bay City, Mich., has shipped a combination shovel and drag line, capacity 1,500 cu.yd. daily, to California Alder-Gulch for use at its placer gold property, near Virginia City, Mont. In addition, placer production by dredge is expected to start by the end of October, according to C. J. Trauerman, consulting engineer. A pole line is being built from Virginia City to furnish power.

■

Union Offers Rand Area. The Union of South Africa government has asked for bids covering leases on a total of 6,000 mining claims lying between the producers in the Far East Rand section of the Witwatersrand and the Sub Nigel gold property at Heidelberg. This ground is considered prospectively favorable area for the discovery of extensions of the main Rand ore-bearing formations.

■

Arizona Magma Reopening. Reopening of the Arizona Magma gold property, near Chloride, Ariz., was scheduled for Oct. 10, according to Cliff Carpenter, president. About 45 men will be employed. Contracts for installing a 50-ton floation mill, electric hoisting equipment, and a compressor have been let to San Francisco firms. They total about $50,000 in value.

■

Alabama Gold Development. Southern Gold, Inc., New York, is taking over for development the Hillabee mine (Hog Mountain), near Alexander City, Ala. The company is prepared to build a 500-ton mill if sufficient ore is blocked out. A report on the property, showing an average value of $7 in gold per ton in several of the known veins has been made by Edward H. Emerson, consulting engineer, Brooklyn, N. Y.

Bulolo to Get New Areas. Placer Development will probably transfer its Bulowat and Burnside placer holdings, in the New Guinea field, to Bulolo Gold Dredging, the operating company in which it has a large interest. About 40,000,000 cu.yd. of gravel running 30c. a cubic yard is indicated on the Bulowat ground. At least one additional dredge will be ordered by Bulolo to equip this property and, if operating conditions are favorable, another may be added, giving the company four dredges in all.

■

Homestake Dividend Up. Homestake Mining, largest gold producer in the United States, whose operations are described in the current issue of *E. & M. J.*, has declared a dividend of 65c. a share, payable on Oct. 26 to stockholders of record, Oct. 20. The company had been paying monthly dividends of 50c. a share, the increase meaning a change in the annual rate from $6 to $7.80. In addition, the company paid an extra dividend of $1 a share in September.

■

Idaho-Maryland Milling Plans. Idaho-Maryland, gold producer at Grass Valley, Calif., is milling 175 tons of ore daily at its two milling plants. Plans for a new mill are under consideration and experiments with flotation are being continued at the Brunswick mill.

■

Cory Builds Gravel Plant. The shaft of Cory Mining, near Magalia, Calif., has been completed to the 503 level. A new headframe is being constructed and a gravel-washing plant, with a capacity of 150 tons daily. Mining operations will start when the surface plant is finished.

■

Utah Gold Reports Find. A discovery of high-grade gold ore on the 106 sublevel of the Fortuna mine, operated by Utah Gold, 14 miles north of Beaver, Utah, has been reported by John Bestelmeyer, superintendent. The find was made at the northeast end of the level. It has been drifted on for 20 ft. A small ore bin is being constructed to permit shipments of ore.

■

Snelling Orders Dredge. Snelling Gold Dredging, of which C. H. Thurman is president, has placed a contract for a steel dredge hull. Construction of a gold dredge at its property, on the Merced River, below ground worked by La Grange and above the old Yosemite Gold holdings, will be started as soon as the hull is ready.

■

To Drag San Miguel River. A drag line has been shipped to the property of San Miguel Explorations, Inc., on the San Miguel River, near Naturita, Colo. It will be used in working placer gold deposits along the river. The company, which has been financed in Kansas City, is reported to have 24 miles along the river under lease.

■

Kilo-Moto Reports Reserves. Kilo-Moto Gold, leading gold producer of the Belgian Congo, reports that it has reserves in sight containing 45,000 kg. of gold (or 1,446,750 oz.). Production in 1930, for which the annual report has just been issued, totaled 4,597 kg. Of this, 3,222 kg. was recovered by washing plants; 1,309 kg. by the mills; and 66 kg. by the dredges. Production from both the mills and dredges is increasing this year. A third power station is being built on the Nzoro River at Moto. The amalgamation section of the new Nizi concentrator has been put in operation and the flotation unit will be put in commission early in 1932. A third dredge is being built for the Moto deposits.

■

Yellow Pine Tunnel Record. In August, Yellow Pine, operating at Stibnite, Valley County, Idaho, advanced its Monday tunnel a distance of 664 ft. in August, creating a new tunnel driving record for Idaho. Although Stewart Campbell, state mine inspector, hazarded the opinion that it might be a world record, this total has been surpassed at the Trepca Mines, Yugoslavia; Cerro de Pasco, Peru; and Ojuela, Mexico. About 200 men are employed at the property, which carries gold and quicksilver deposits. A mill to treat gold ore, power plant, and other buildings are being constructed.

■

Nickel Cuts Salaries. International Nickel, leading nickel-copper producer, cut salaries of employees drawing monthly incomes by 10 per cent, effective Oct. 1. In accordance with a policy adopted some time ago, no change has been made in the basic pay for employees paid on a daily basis.

■

Spence Bear Lake Report. F. S. Spence, a member of the Canadian Geological Survey, is reported to have completed his report on the discoveries at Great Bear Lake, in Northwest Territories. Its publication is being awaited with interest, as the silver and radium deposits there have been widely acclaimed in the press. Mr. Spence spent the summer at Great Bear Lake examining the holdings of Eldorado Mines, Dominion Explorers, and Consolidated Mining & Smelting.

■

Joplin Meeting Attracts 300. More than 300 persons registered during the convention of the Western division of the American Mining Congress and the regional meeting of the A.I.M.E. at Joplin, Mo., on Sept. 28-30. Lack of space in this issue prevents publication of an account of the proceedings by J. H. Wadleigh, Joplin correspondent. It will appear in the Oct. 26 issue.

■

Crown Diamond Closes. Operations have been suspended at the Crown Diamond mine, controlled by African & European Investment, in the Kroonstad district, Orange Free State, Union of South Africa. Chaotic market conditions are given as the reason. Production in the fiscal year ended June 30, 1930, was 113,299 carats, and in the six months ended Dec. 31, 1930, 56,875 carats.

■

Itogon Mill Addition. Itogon Mining, operating in the Benguet gold district, of the Philippine Islands, has completed enlarging its milling capacity to 180 tons of ore daily. Because expansion of the mine lagged behind mill work, not enough stoping faces in average-grade gold ore have been available to supply the plant.

Royal Development to Receivers. The Chemung Canal Trust Company, of Elmira, N. Y., and Charles McLoughlin, attorney, of Rochester, have been appointed receivers for Royal Development, which operated a copper property in Washington. Action was started nearly a year ago by the New York Attorney General, and an examination of the mine was made by Rogers, Mayer & Ball. In their opinion, the mine contains no commercial ore. A 200-ton mill was built last year at the property, near Leavenworth, but was shut down shortly after being completed. The company claimed that it had developed a huge, low-grade deposit containing several million tons of material averaging 2 per cent copper.

■

Mohawk Working One Shaft. Only one shaft is now in operation at the Mohawk Mining property, in the northern section of the Michigan copper district. The No. 6 is shipping about 1,200 tons of ore daily to the mill. No. 1 shaft was closed recently, after reserves in its area had been exhausted. About four or five years' reserves are in sight in No. 6 area. Mohawk continues to store concentrate at its mill, rather than convert it into copper with present low prices.

■

C. & H. Remodels Rockhouse. A concrete foundation has been built and new steel is being erected at the No. 2 rockhouse, or crushing plant, of the Centennial unit of Calumet & Hecla Consolidated, near Calumet, Mich. Capacity of the plant will be increased by installation of larger crushers. This unit is expected to become of increasing importance as the result of development on the Kearsarge amygdaloid formation south of the present producing area. Three new levels will be opened below the No. 39, which showed ore for a considerable distance.

■

F. W. Bradley Saunders Medalist. The Saunders gold medal, presented annually by the A.I.M.E. for distinguished achievement in the mining industry, will be awarded this year to F. W. Bradley, of San Francisco. Last year, F. W. Maclennan won the award. Mr. Bradley is perhaps best known as the man who brought the Alaska Juneau gold mine to success. He is also president of Bunker Hill & Sullivan, Idaho's premier lead producer, and of Treadwell Yukon, an exploration company with wide interests. Through the Sullivan electrolytic zinc plant he has played an important part in zinc hydrometallurgy and in the conservation of zinc resources.

■

Sullivan Cuts Ore at Star. Sullivan Mining, subsidiary of Bunker Hill & Sullivan and Hecla Mining, near Burke, Idaho, has cut 14 ft. of lead-zinc ore in its Star property. The strike was made in the old Star tunnel, about 400 ft. above the No. 5 and 2,700 ft. above the Star crosscut. The ore was found in the Iron Crown vein within 15 ft. of the old workings. According to L. E. Hanley, superintendent of the Hecla and Star mines, 4 ft. of the ore is high-grade, with samples showing 17 per cent lead, 22 per cent zinc, and 8 oz. of silver per ton.

Daily Prices of Metals

Sept. / Oct.	Electrolytic Copper	Straits Tin	Lead		Zinc
	Refinery	New York	New York	St. Louis	St. Louis
24	6.775	22.875@23.125	4.40	4.225	3.70
25	6.775	22.00@23.00	4.40	4.225	3.70
26	6.775	22.00@22.50	4.40	4.225	3.70
28	6.775	22.00@22.375	4.40	4.225	3.70
29	6.775	22.00@22.25	4.40	4.225	3.65@3.675
30	6.775	22.25@22.50	4.40	4.225	3.65
Av'ge	6.775	22.406	4.400	4.225	3.685
1	6.775	22.125	4.40	4.225	3.60
2	6.775	22.10	4.25	4.075	3.60
3	6.775	22.375	4.075	3.85	3.60
5	6.775	22.25	4.00	3.825	3.575@3.60
6	6.775	22.25	4.00	3.825	3.55@3.60
7	6.775	22.375	4.00	3.825	3.50
Av'ge	6.775	22.246	4.121	3.938	3.577

Average prices for calendar week ended September 26, 1931, are: Copper, 6.775c.; Straits tin, 22.946c.; New York lead, 4.400c.; St. Louis lead, 4.217c.; Zinc, 3.700c.; Silver, 29.375c.

Average prices for calendar week ended October 3, 1931, are: Copper, 6.775c.; Straits tin, 22.215c.; New York lead, 4.321c.; St. Louis lead, 4.138c.; Zinc, 3.635c.; Silver, 28.021c.

The above quotations are our appraisal of the major markets for domestic consumption based on sales reported by producers and agencies. They are reduced to the basis of cash, New York or St. Louis, as noted. All prices are in cents per pound.

Copper, lead, and zinc quotations are based on sales for both prompt and future deliveries; tin quotations are for prompt delivery only.

In the trade, copper prices are quoted on a delivered basis; that is, delivered at consumer's plant. As delivery and interest charges vary with the destination, the figures shown above are net prices of refineries on the Atlantic seaboard. Delivered prices in New England average 0.225c. per pound above those quoted.

Quotations for copper are for the ordinary forms of wirebars and ingot bars. For ingots an extra 0.05c. per pound is charged; for slabs, 0.075c.; and for cakes, 0.125c. up depending on weight. Cathodes are sold at a discount of 0.125c. per pound.

Quotations for zinc are for ordinary Prime Western brands. Zinc in New York is now quoted at 0.35c. per pound above St. Louis, this being the freight differential. The contract price for High-Grade zinc delivered in the East and Middle West is 1c. above the St. Louis price for Prime Western.

Quotations for lead reflect prices obtained for common lead, and do not include grades on which a premium is asked.

Silver, Gold, and Sterling Exchange

Sept.	Sterling Exchange "Checks"	Silver		Gold, London	Oct.	Sterling Exchange "Checks"	Silver		Gold, London
		New York	London				New York	London	
24	3.89	29 1/8	15 7/8	103s 5d	1	3.95	28	15 15/16	103s 8d
25	3.60	31	19 1/2	114s 9d	2	3.92	27 7/8	15 15/16	104s 3d
26	3.85	28 3/4	16 3/4	.....	3	3.84	28	16 3/8	.....
28	3.85	28 5/8	16 3/8	108s 1d	5	3.78	28 7/8	17 1/4	108s 6d
29	3.85	28 5/8	16 3/8	105s 3d	6	3.89	28 3/4	16 7/8	108s 3d
30	3.90	27 1/2	16 3/16	105s 3d	7	3.89	29 1/8	16 7/8	105s 8d

Average week ended September 30: Silver, 28.854c.; Sterling Exchange, $3.82333

Average for week ended October 7: Silver, 28.438c.; Sterling Exchange, $3.87833

New York quotations are as reported by Handy & Herman and are in cents per troy ounce of silver, 999 fine. London silver quotations are in pence per troy ounce of bar silver, basis of 925 fine. Sterling quotations represent the demand market in the forenoon. Cables commanded one-quarter cent premium at noon on Oct. 7.

London

Sept. / Oct.	Copper Standard		Electrolytic (Bid)	Tin		Lead		Zinc	
	Spot	3 M		Spot	3 M	Spot	3 M	Spot	3 M
24	33 1/4	34 1/4	38 1/2	126 1/2	130 3/8	14 1/2	14 1/2	13	13 3/8
25	35 1/2	36 5/8	43	132 1/4	136 1/2	15 1/2	15 1/2	13 13/16	14 5/16
28	33 7/8	35 1/2	41 1/4	125	129 1/2	13 3/4	13 3/4	12 7/8	13 3/8
29	33 3/4	35 3/8	41	122 1/2	126 1/2	14 7/16	14 1/4	12 5/8	13 1/8
30	33 3/8	34 3/8	40 1/2	122 7/8	126 3/4	14 3/16	14	12 7/8	13 5/16
1	32 3/8	33 1/4	40	120 1/4	124 1/8	13 1/8	13	12 5/16	12 7/8
2	32 1/4	33 1/4	39 1/2	122	125 1/2	13	13	11 7/8	12 1/2
5	34 5/8	35 5/8	41	125 3/4	130	13 1/4	13 3/8	12	12 5/8
6	33 1/8	34 1/2	40 1/2	124 1/2	128 5/8	12 3/4	13	12	12 11/16
7	33 13/16	34 13/16	41	124 1/8	128 1/4	12 3/4	13	12 3/16	12 13/16

Prices for lead and zinc are the official price for the morning session of the London Metal Exchange; prices for copper and tin are the official closing buyers' prices. All are in pounds sterling per long ton (2,240 lb.).

Copper Holds at 7c.—Lead and Zinc Lower

New York, Oct. 8, 1931

Interest in the market for non-ferrous metals centered in the announcement from Washington of a plan to mobilize the nation's credit for banks, industry, and agriculture. The news created a better feeling in all commodity markets. But until consumer buying shows some definite signs of picking up, producers of metals are disposed to move slowly.

Inquiry for first quarter 1932 copper showed some improvement, especially in the last two or three days, and the market closed steady on the basis of 7c. per pound, delivered Connecticut. Early in the period there was some doubt as to whether the price could be maintained at 7c., owing to the quiet prevailing and the disrupted state of the financial situation, abroad as well as here. The constructive steps taken by President Hoover did much to halt the wave of liquidation that had demoralized the security markets. Aside from this development, some traders appeared to realize that at least two events scheduled for the near future might change the complexion of the market. A meeting of producers will start soon to consider steps to help the industry, and before long attention will center around the move for a tariff. As for curtailment in production, both producers and consumers realize that the current price alone will bring about a downward trend in output.

Zinc was dull and slight selling pressure sufficed to unsettle prices. Business went through as low as 3.50c., a net loss of 20 points for the last two weeks. The daily rate of domestic production for September was 712 tons, against 692 tons in August. Stocks at the end of September amounted to 130,155 tons, against 129,701 tons a month previous. Shipments during September fell to 20,902 tons.

The lead market pursued the even tenor of its way until late on Oct. 2, when the American Smelting & Refining Company decided to reduce its contract price from 4.40c., New York, to 4.25c. A reduction had been considered even before that time on account of the weakness in the foreign market, which had come to domestic parity, and because of the fact that business had recently been very dull and promised to continue so in October. On Oct. 5, the A. S. & R. came down to 4c., New York, and the market has remained at that level, with St. Louis at 3.825c.

Silver was quite animated on continued support from speculators who still believe that the metal will figure largely in restoring the world's credit machinery.

Quicksilver demand remains below normal and price irregularity continues. There were sellers at $74 to $75 per flask, depending on quantity.

Metal Statistics

Monthly Average Prices of Metals

(See daily price table for basis of quoting)

Silver

	New York 1930	New York 1931	London Spot 1930	London Spot 1931	Sterling Exchange 1930	Sterling Exchange 1931
January	45.000	29.423	20.896	13.810	486.447	485.260
February	43.193	26.773	20.008	12.432	485.784	485.551
March	41.654	29.192	19.298	13.524	485.933	485.596
April	42.428	28.279	19.554	13.120	486.019	485.764
May	40.736	27.650	18.850	12.858	485.724	486.188
June	34.595	27.250	16.049	12.707	485.625	486.291
July	34.346	28.255	15.928	13.197	486.300 (a)	485.349
August	35.192	27.524	16.283	12.815	486.839	485.284
September	36.315	28.180	16.738	14.101	485.888	451.245
October	35.846	.....	16.563	.....	485.719	.....
November	35.908	.....	16.625	.....	485.454	.....
December	32.635	.....	15.201	.....	485.413	.....
Year	38.154	.....	17.666	.....	485.929	.....

New York quotations, cents per ounce troy, 999 fine. London, pence per ounce, sterling silver, 925 fine. Sterling exchange in cents.
(a) Revised.

Copper

	F.O.B. Refinery Electrolytic 1930	F.O.B. Refinery Electrolytic 1931	London Spot Standard 1930	London Spot Standard 1931	London Spot Electrolytic 1930	London Spot Electrolytic 1931
January	17.775	9.838	71.469	44.938	83.250	47.524
February	17.775	9.724	71.419	45.372	83.500	47.950
March	17.775	9.854	69.202	44.818	83.405	47.699
April	15.621	9.392	62.075	42.694	74.338	45.375
May	12.756	8.665	53.159	38.897	59.545	42.175
June	12.049	8.025	50.003	35.827	56.750	38.966
July	11.023	7.698	48.277	34.402	52.522	37.293
August	10.693	7.292	47.525	32.572	50.725	35.388
September	10.310	6.988	46.264	31.503	49.500	36.148
October	9.597	.....	43.030	.....	45.772	.....
November	10.113	.....	46.134	.....	48.963	.....
December	10.300	.....	46.771	.....	50.065	.....
Year	12.982	.....	54.611	.....	61.528	.....

New York quotations, cents per pound. London, pounds sterling per long ton.

Lead

	New York 1930	New York 1931	St. Louis 1930	St. Louis 1931	London 1930 Spot	London 1930 3 Mos.	London 1931 Spot	London 1931 3 Mos.
January	6.250	4.802	6.100	4.604	21.545	21.571	13.872	13.905
February	6.236	4.552	6.086	4.340	21.188	21.097	13.444	13.550
March	5.662	4.527	5.542	4.276	18.807	18.940	13.128	13.355
April	5.537	4.412	5.428	4.164	18.319	18.363	12.375	12.606
May	5.523	3.818	5.408	3.651	17.795	17.861	11.491	11.778
June	5.410	3.917	5.310	3.761	17.941	17.994	11.582	11.952
July	5.250	4.400	5.149	4.225	18.160	18.063	12.731	12.899
August	5.488	4.400	5.340	4.225	18.294	18.178	11.944	11.994
September	5.500	4.400	5.348	4.217	17.909	17.798	11.932	12.026
October	5.151	.....	4.999	.....	15.747	15.674	.....	.....
November	5.100	.....	4.950	.....	15.954	15.931	.....	.....
December	5.100	.....	4.950	.....	15.283	15.292	.....	.....
Year	5.517	.....	5.384	.....	18.077	18.064	.....	.....

New York and St. Louis quotations, cents per pound. London, pounds sterling per long ton.

Tin and Cadmium

	New York Straits 1930	New York Straits 1931	London Spot 1930	London Spot 1931	Cadmium 1931
January	38.851	26.137	175.466	115.798	67.115
February	38.675	26.315	173.750	117.919	55.000
March	36.798	27.065	164.851	121.852	55.000
April	36.077	25.222	162.638	112.775	55.000
May	32.108	23.221	144.818	104.331	55.000
June	30.336	23.478	136.300	104.966	55.000
July	29.822	24.978	134.511	111.478	55.000
August	30.044	25.738	134.988	114.875	55.000
September	29.647	24.618	132.631	117.813	55.000
October	26.802	.....	117.451	.....	.....
November	25.904	.....	113.519	.....	.....
December	25.262	.....	111.560	.....	.....
Year	31.694	.....	141.873	.....	.....

New York quotations, cents per pound. London, pounds sterling per long ton.

Zinc

	St. Louis 1930	St. Louis 1931	London 1930 Spot	London 1930 3 Mos.	London 1931 Spot	London 1931 3 Mos.
January	5.229	4.035	19.634	20.241	12.747	13.113
February	5.180	4.012	19.209	19.778	12.303	12.694
March	4.934	4.002	18.304	18.810	12.190	12.676
April	4.843	3.717	17.819	18.378	11.353	11.838
May	4.641	3.306	16.639	17.330	10.484	10.875
June	4.441	3.416	16.422	17.038	11.270	11.750
July	4.350	3.893	16.171	16.777	12.280	12.802
August	4.360	3.817	15.953	16.469	11.444	12.028
September	4.270	3.744	15.773	16.080	11.571	12.063
October	4.050	.....	14.446	14.935	.....	.....
November	4.266	.....	14.706	15.238	.....	.....
December	4.099	.....	13.762	14.214	.....	.....
Year	4.556	.....	16.570	17.107	.....	.....

St. Louis quotations, cents per pound. London pounds sterling, per long ton.

Antimony, Quicksilver, and Patinum

	Antimony (a) New York 1930	Antimony (a) New York 1931	Quicksilver (b) New York 1930	Quicksilver (b) New York 1931	Platinum (c) New York 1930	Platinum (c) New York 1931
January	8.606	7.317	121.192	103.000	61.923	36.000
February	8.830	7.069	120.500	100.205	59.909	34.000
March	8.236	7.127	118.808	100.423	54.769	29.538
April	7.740	6.888	114.000	102.077	46.462	26.346
May	7.454	6.524	117.269	101.140	46.000	24.980
June	7.057	6.342	118.600	92.058	46.000	37.115
July	6.976	6.802	117.462	85.808	43.692	40.000
August	7.839	6.596	116.000	80.115	41.462	40.000
September	7.773	6.542	113.620	76.300	36.080	40.000
October	7.288	.....	110.596	.....	36.000	.....
November	7.105	.....	106.717	.....	36.000	.....
December	7.099	.....	105.346	.....	36.000	.....
Year	7.667	.....	115.009	.....	45.358	.....

(a) Antimony quotations in cents per pound, for ordinary brands. (b) Quicksilver in dollars per flask of 76 lb. (c) Platinum in dollars per ounce.

Pig Iron[1] and Aluminum

	Bessemer 1930	Bessemer 1931	Basic 1930	Basic 1931	No. 2 Foundry 1930	No. 2 Foundry 1931	Aluminum 1930	Aluminum 1931
January	19.00	17.50	18.50	17.00	18.50	17.00	24.300	23.300
February	19.00	17.29	18.50	16.79	18.50	16.79	24.300	23.300
March	19.00	17.00	18.50	16.50	18.50	16.50	24.300	23.300
April	19.00	17.00	18.50	16.50	18.50	16.50	24.300	23.300
May	19.00	17.00	18.50	16.38	18.50	16.44	24.300	23.300
June	19.00	17.00	18.50	15.50	18.50	16.00	24.140	23.300
July	18.62	17.00	18.12	15.50	18.12	16.00	23.300	23.300
August	18.50	17.00	18.00	15.50	18.00	16.00	23.300	23.300
September	18.38	17.00	17.76	15.50	17.88	16.00	23.300	23.300
October	17.85	.....	17.00	.....	17.22	.....	23.300	.....
November	17.50	.....	17.00	.....	17.00	.....	23.300	.....
December	17.50	.....	17.00	.....	17.00	.....	23.300	.....
Year	18.53	.....	17.99	.....	18.02	.....	23.787	.....

Iron in dollars per long ton. Aluminum in cents per pound, 99 per cent grade.
[1]F.o.b. Mahoning and Shenango Valley furnaces; freight to Pittsburth, $1.76

Monthly Crude Copper Output in Short Tons

	1929	1930	1931 May	1931 June	1931 July	1931 Aug.
Domestic						
Alaska shipments	21,947	18,953	1,215	1,303	1,048	748
Calumet & Arizona	65,246	45,161	.....	.....	.....	.....
Magma	19,118	15,940	1,208	1,437	1,229	.....
Miami	29,567	34,568	2,272	2,174	2,032	.....
Nevada Consolidated	133,140	70,990	.....	(d) 16,504	.....	.....
Old Dominion (a)	11,172	10,428	992	600	575	539
Phelps Dodge (b)	111,026	72,308	5,176	5,178	5,179	5,166
United Verde Extension	29,669	21,908	1,685	1,642	.....	.....
Tennessee Corporation	7,870	7,772	992	833	742	.....
Foreign						
Andes Copper	60,538	47,428	3,498	3,498	.....	.....
Braden	88,155	79,923	8,594	8,593	8,595	.....
Boleo, Mexico	12,898	13,940	.....	(d) 3,107	.....	.....
Chile	(c) 150,247	89,100	7,117	7,122	.....	.....
Furukawa, Japan	17,767	18,536	1,517	1,505	1,431	.....
Howe Sound	21,516	22,633	.....	(d) 4,001	.....	.....
Messina	(c) 7,100	(c) 7,600	868	870	832	897
Mt. Lyell	9,731	10,878	.....	.....	.....	.....
Sumitomo, Japan	20,180	15,429	1,571	1,286	1,255	.....

(a) Includes Arizona Commercial. (b) Moctezuma is included. (c) Fiscal year. (d) Three months.

Monthly Production of Primary Copper from U. S. Mines and Daily Rate (Short Tons)

	1929 Monthly Production	1929 Daily Rate	1930 Monthly Production	1930 Daily Rate	1931 Monthly Production	1931 Daily Rate
January	86,324	2,785	67,838	2,188	48,059	1,550
February	84,735	3,026	59,196	2,144	47,504	1,697
March	93,698	3,023	61,216	1,975	48,702	1,571
April	94,902	3,163	60,450	2,015	46,452	1,548
May	93,392	3,013	60,238	1,943	45,580	1,470
June	82,354	2,745	56,743	1,891	44,473	1,482
July	79,229	2,556	54,249	1,750	38,228	1,233
August	78,885	2,545	56,779	1,832	38,925	1,256
September	79,402	2,647	56,584	1,886	.....	.....
October	82,575	2,664	55,954	1,805	.....	.....
November	75,934	2,531	53,141	1,771	.....	.....
December	74,772	2,412	48,518	1,565	.....	.....
Total	1,006,203	.....	690,263	.....	357,923	.....
Monthly average	83,850	.....	57,522	.....	44,740	.....
Av. of daily rate	.....	2,757	.....	1,891	.....	1,473